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CAMERON'S CHEMISTRY OF AGRICULTURE

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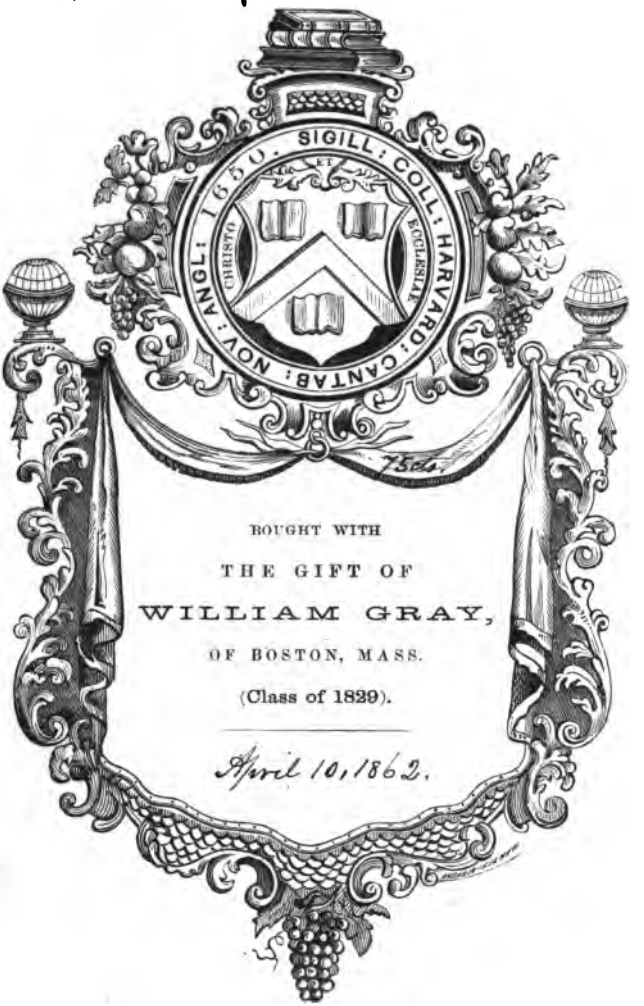

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CHEMISTRY OF AGRICULTURE.

THE FOOD OF PLANTS:

INCLUDING

THE COMPOSITION, PROPERTIES, AND ADULTERATION

OF

MANURES.

BY

CHARLES A. CAMERON, M.D.,

PROFESSOR TO THE DUBLIN CHEMICAL SOCIETY; LECTURER ON CHEMISTRY AND NATURAL PHILOSOPHY IN THE ORIGINAL SCHOOL OF MEDICINE, DUBLIN, ETC., ETC.

"Nihil agricultura melius, nihil dulcius, nihil libero homine dignius."—CICERO.

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TO

SIR ROBERT KANE, F.R.S., V.P.R.I.A., &c. &c.,

PRESIDENT OF THE QUEEN'S COLLEGE, CORK; DIRECTOR OF THE MUSEUM OF IRISH INDUSTRY.

My dear Sir Robert,

It is with no ordinary feelings that I dedicate to you this little work on Agricultural Chemistry.

Your career, distinguished not more by brilliant achievements in the field of science than by the zeal and success with which you have labored to ensure their practical application, confirms the appropriateness of this dedication.

It cannot but be to me a source of the sincerest gratification to have my name thus associated with that of one who is so intimately identified with the scientific and industrial progress of our country.

Believe me,

My dear Sir Robert,

Yours most faithfully and obliged,

CHARLES A. CAMERON.

PREFACE.

A PORTION of the following treatise formed the subject of some lectures delivered by me at meetings of the agricultural section of the Dublin Chemical Society. Many of the members, and others present, conceiving that such a course would be advantageous to the agricultural classes, requested me to publish the substance of those lectures in a more permanent and popular form.

In acceding to their request I have endeavoured, when practicable, to avoid the use of scientific phraseology, in order that the general reader, for whose perusal this little book has been specially written, may not be unnecessarily inconvenienced. At the same time I may here observe, that it would be quite impossible to treat of any department of science without the introduction of terms which, to a reader for the *first time*, must appear embarrassing, if not discouraging. I would, however, urge upon all readers, under such circumstances, the necessity of perseverance—a little patience and application, and they will find ample compensation in the discovery which inevitably follows—that the difficulties which at first appeared unconquerable are gradually disappearing, and also in the reflection that they will have acquired knowledge, the advantages of which cannot be over estimated.

I am aware that a great deal has been done to extend and promote a knowledge of agricultural chemistry by means of several deservedly popular works on the subject; but vast is the work which remains still unaccomplished; indeed, it would seem to be a task to which there are no limits.

It is my most earnest desire to see a more general recognition of the importance of a scientific application of chemistry to agriculture; and being convinced that the future prosperity of the country is, to a great extent, involved in such a recognition, I will, indeed, be gratified if, by the publication of the following pages, I have in any degree contributed to awaken a spirit of enquiry amongst the cultivators of the soil on this most important subject.

CHARLES A. CAMERON.

DUBLIN, 17, ELY-PLACE,
15th October, 1857.

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ERRATA.

Page 20, line 4 from the top, after "sulphur" read "silicium."

Page 29, first line, for "or" read "and."

CHEMISTRY OF AGRICULTURE.

I.—IMPORTANCE OF CHEMISTRY IN RELATION TO AGRICULTURE AND THE ARTS.

At the present period of the world's history it fortunately requires no argument to enforce the importance of Chemistry as an eminently useful science. She has so surrounded herself with witnesses of her universal sway, that the mind which doubts her potency must be obtuse indeed. Her laws, written in the achievements of modern science, demand, and must receive, unqualified obedience. The impalpable vapour under her dominion hurls with rapidity the most enormous weight, strikes with the force of tons, or falls with the delicacy of an infant's touch. At her mandate the unseen messenger annihilates space, and conveys our thoughts to the ends of the earth, even as we are engaged in giving expression to them. At her command light comes forth—illumination, the direct result of her agent—electricity, or of gas. She arrests the sunbeam, and it becomes her artist to paint the lineaments of nature in its own perfection of truth and beauty. All this has Chemistry accomplished. Steam, electricity, gas, and photography, cannot but command attention by the great and incalculable benefits which have resulted to mankind from

their employment. Nor is Chemistry yet exhausted; there are in her vast domain many varied departments which, when investigated, will equally awaken admiration.

Chemistry is so intimately interwoven with our existence—with all that tends to promote our comfort, that it is incumbent upon every one, no matter what his position in life may be, to acquire, at least, an elementary knowledge of the laws which perform so important a part in the economy of nature. This must be self-evident to every reasoning mind, when informed that Chemistry, in her operations, is ever active, preparing the food—vegetable and animal—which sustains us; elaborating textures for the garments which clothe us; fabricating materials for the dwellings which shelter us; beside us when we sleep, administering to us the breath of life—the vital air we breathe; abroad with us whilst waking, holding in her mighty grasp all that meets our gaze; in short, there exists nothing in the broad expanse of nature independent of her influence. Solids, liquids, gases; heat, light, electricity—all attest the potency of Chemistry.

The importance of the science of Chemistry has, of late years, met with extensive recognition, resulting in the gratifying fact, that in the various arts and manufactures the greatest improvements have taken place, not only in the quality, but also, in a great number of instances, in the quantity of the productions. In all cases it is clearly demonstrated that in those countries where Chemistry has been most studied, the greatest degree of perfection has been attained, and as a consequence their manufactures command almost exclusively the markets of the world. This patent fact should surely operate as a powerful incentive to awaken an earnest enquiry into a matter which so materially interposes to advance the social position of a community.

Without an effort to keep pace with the onward march of

science, any country must fail, effectively to bear up against a competition which its ignorance of Chemistry must cause to be so unequal. How important then does it become to the artist, the manufacturer, and the agriculturist, assiduously to follow up the progress which, day after day, the skilful application of Chemistry is indicating.

The resources of Chemistry are unbounded; from her varied storehouse who can foresee what new productions may come forth at once to enrich and instruct us! The recent production of the metal, aluminium—an abundant constituent of common earth—affords an apt illustration. Fifty years since, the illustrious Davy discovered the key which led to this result. By the magic potency of electricity he produced from common potash the metal potassium, never before beheld by human eye; and although at the period of its discovery, remarkable as it was, it led to no immediate practical results, yet, after an interval of so many years we find, in our own day, that by an application of the knowledge derived from Davy's celebrated experiment, aluminium has been produced—a metal possessing such valuable properties, that when a simple process of extraction shall have been attained, of which there can be but little doubt, it may, in all probability, effect a complete revolution in many of the arts in which silver and various other metals have hitherto been regarded as indispensable.

Providence has, no doubt, so arranged, that the noble attribute of intellect with which man is endowed, should not lie dormant. It has been decreed that it must *think*; and often by the withholding for a season of a particular production to exercise man's faculties by compelling him to proceed in search of a substitute, that not only has he succeeded in securing the object of his pursuit, but, in many instances, discovered one of considerably greater value than that, the withdrawal of which, in the first instance, he regarded as the

greatest privation; and not only this, but in the progress of his investigations to attain this end, he may make, and, as is well known, has frequently made, discoveries the most valuable.

An interesting example of the scarcity of an article of every-day use, or what amounts to the same thing, a difficulty in obtaining it, exercising the ingenuity of the mind to procure a supply, is afforded by the French chemist Le Blanc's important discovery of the process of making carbonate of soda from common salt. Soda, it may be here mentioned, is largely employed in the manufacture of soap and glass—two articles, on the production of which so much depend the interests of civilization, that their absence or excessive dearness must be severely felt. During a period of the war with Great Britain, France was prevented from obtaining her supply of soda from Spain, in which country that substance was prepared in considerable quantities by burning sea-weed. In this dilemma the First Napoleon offered a large reward to whoever should succeed in producing it artificially, and Le Blanc, in his chemical researches to obtain the reward, discovered at last that it could be obtained by a cheap process from common salt, thus conferring a boon, not alone on his country, but upon the whole civilized world, by placing within the reach of all classes soap and glass, independently of many other important productions. How deeply should this fact alone impress us with the importance of chemical knowledge!

Chemistry has revealed to us the composition of vegetable bodies, and thus points out to us the food necessary to promote the growth of plants. Among the many articles which are useful for this purpose are *coprolites*, a peculiar substance found in many districts of England in considerable quantities. Chemical analysis has proved these coprolites to be composed of phosphoric acid and lime—materials which are so indispensably necessary for the development of most of our cultivated

plants—but coprolites are so extremely hard and insoluble that they could not, in their natural state, supply the required nourishment; the plant, so to speak, could not drink it in through its rootlets; but here Chemistry steps in to our aid, and shows *how* the coprolites can, by the action of one of the cheapest and most abundant acids, be rendered soluble, and, therefore, available. Thus a substance, the discovery of which is but an event of yesterday, may, in the hands of enlightened and scientific agriculturists, be the means of conferring fertility on many of our exhausted fields, by restoring to them the *phosphates*, which the crops of countless years had robbed them of.

These reflections bring us more immediately to the consideration of the agricultural branch of chemical science, to which our remaining observations in this introduction will be limited.

There can be no doubt whatever but that by closely following up the design, the at present empirical art of agriculture can be elevated to the rank of a science; and when the present state of agriculture in these countries, more especially in Ireland, is considered, it cannot but be regarded as a question demanding the serious attention of all engaged in agricultural pursuits, as well as those who are not; the interests of the producers as well as the consumers being both involved in it, resolving itself as it does into two momentous points; in the first instance, the production of a sufficient quantity of food available to meet the wants of our teeming population; and in the second instance, to produce a supply at so cheap a cost as to effectually prevent the introduction of foreign corn into this kingdom.

With respect to the first of these conditions it is in the highest degree satisfactory to learn, from the last agricultural census, that of late a considerable addition has been made to

the area of land under cultivation, and it is now to be hoped that each succeeding year will find the number of acres uncultivated still further diminished; this, together with the introduction of a more improved, because more scientific system, must assuredly eventuate, if not in completely leaving us independent of foreign supplies, certainly in diminishing to a considerable extent, the enormous imports which at present our deficiency in knowledge compels us to require.

The distinction between agriculture as a *science*, and agriculture as an *art*, has been so happily and ably drawn by the renowned chemist, Baron Von Liebeg, that we have the greatest satisfaction in quoting the following passage on this subject from that eminent and most distinguished authority:—

"Agriculture is both a science and an art. The knowledge of all the conditions of the life of vegetables, the origin of their elements, and the sources of their nourishment, forms its scientific basis.

"From this knowledge we derive certain rules for the exercise of the ART, the principles upon which the mechanical operations of farming depend, the usefulness or necessity of these for preparing the soil to support the growth of plants, and for removing every obnoxious influence. No experience, drawn from the exercise of the art, can be opposed to true scientific principles, because the latter should include all the results of practical operations, and are, in some instances, solely derived therefrom. Theory must correspond with experience, because it is nothing more than the reduction of a series of phenomena to their last causes.

"A field in which we cultivate the same plant for several successive years becomes barren for that plant in a period varying with the nature of the soil: in one field it will be in three, in another in twenty, in a fourth in a hundred years. One field bears wheat, and no peas; another beans or turnips,

but no tobacco; a third gives a plentiful crop of turnips, but will not bear clover. What is the reason that a field loses its fertility for one plant, the same which at first flourished there? What is the reason one kind of plant succeeds in a field where another fails?

"*These questions belong to Science.*

"What means are necessary to preserve to a field its fertility for one and the same plant?—What, to render one field fertile for two, for three, for all plants?

"*These last questions are put by Art, but they cannot be answered by Art.*"

"If the farmer, without the guidance of just scientific principles, is trying experiments to render a field fertile for a plant, which it will not otherwise bear, his prospect of success is very small. Thousands of farmers try experiments in various directions, the result of which is a mass of practical experience, forming a method of cultivation which accomplishes the desired end for certain places; but the same method frequently does not succeed; it, indeed, ceases to be applicable to a second or third place in the immediate neighbourhood. How large a capital, and how much power are wasted in these experiments! Very different, and far more secure is the path indicated by SCIENCE; it exposes us to no danger of failing, but, on the contrary, it furnishes us with every guarantee of success. If the cause of failure—of barrenness in the soil for one or two plants—has been discovered, means to remedy it may readily be found."

The great advances which latterly have been made in agriculture generally is manifestly mainly due to the application of scientific knowledge. The saving in time which has been effected, the advantage derived from the rotation of crops, the soil so sustained in fertility by the introduction of such elements *artificially* as have been withdrawn from it

naturally, must convince the simplest understanding, that to be wilfully ignorant of the principles which have effected these important results is literally to refuse the acceptance of an income doubled in amount.

It is true that within the past half century a very considerable improvement has taken place in the diffusion of knowledge generally, and in proportion as the general intelligence prevails, so will vanish the difficulty of obtaining a recognition of the value of science in its application to agriculture as well as to other pursuits. We have now no longer to contend with an ignorance which, in the days of our grandfathers, insisted that because by the mere scraping of the surface of the ground as much food was produced as supported an existence in indolence, it was futile to adopt a more improved system of *mechanical* agriculture. However, even in those unenlightened times there were some persons of superior intelligence who adopted the improvements, and were amply repaid by the abundance and quality of their harvest. Thus affording proof positive to their sceptical neighbours of the wisdom of their proceedings.

Great, indeed, are the advantages which have flowed from the adoption of improved implements and machinery to the agriculturist, but it is to be feared that *at present* there is too great a tendency to rely *solely* upon mechanical improvements as affording everything essential for the production of large and excellent crops. To a number, far from inconsiderable, *scientific* farming appears a riddle; but like the sceptics, with regard to the advantages of improved machinery, they must find, to their cost, that they have been grievously imposing upon themselves. The quality and quantity of their *scientific* neighbours' crops startle them into the conviction that there must be *something in it*, and thus they become awakened to *enquire*. This once the case, and we may with certainty cal-

culate upon the results—more converts to science—more advocates for her cause—enforcing, by precept and example, that mind must triumph over matter.

By mere observation any man engaged in cultivating the soil is familiar with the fact, that to grow in succession the same crop in the one field must eventuate, sooner or later, in the deterioration of the latter; but a man instructed in scientific principles, not only *observes*, but can *account* for this; and while the former can only *guess*, the latter *knows* what crop is best suited to take the place of its predecessor in any particular soil; or if it should so happen that he required a different crop from that which the soil would best naturally suit, he is furnished with the information which enables him to supply such substances as this other crop may require, and thus accomplish his desire. With such truths before our eyes, the mariner who would attempt to cross the ocean without a compass would appear as judicious as the agriculturist who will persist in the attempt to ensure success in his calling without the aid of science.

There are at the present day many questions connected with agriculture, fraught with very great interest, and which require careful investigation. Among them may be particularly mentioned the importance of obtaining a sufficient supply of fertilizing materials. This is a subject which certainly as yet has not received all the consideration which its paramount importance demands. There are, in these countries, sources from which fertilizers of an excellent description, and in prodigious quantity, could be procured; but it seems unaccountable that advantage has not been taken of them. The sewage of our cities and towns, and the refuse of many of our large manufactories, offer an immense supply of good fertilizing substances, but no extensive means have as yet been used to collect and appropriate them. However, as their value is

becoming better understood, and the necessity of a large supply of fertilizers is daily becoming more urgent, it is very probable that means will shortly be adopted to secure them.

There are in Ireland more than two millions of acres of bog land which, of course, in an agronomic point of view, are utterly worthless. By judicious management this bog land could be reclaimed. Mechanics and Chemistry combined could endow it with all that is requisite to render it available for the production of food. The attempts hitherto made in this direction are comparatively partial, but as they were uniformly attended with success, it seems strange that so certain an undertaking for profitable investment has not received the attention of the capitalist.

At present there is considerable competition for land in Ireland. Irish capitalists, as well as many from the sister island, have already largely invested, and there are daily applications for extensive farms. This being the case, there can be little doubt but of necessity attention will, at no distant period, be directed to the reclaiming of our waste lands. Whenever the two millions of acres of bog land, now lying comparatively useless, and the thousands of acres which, from various other causes, are at present unproductive, are pressed into the service of agriculture, the national prosperity will be increased by the change to an extent scarcely to be estimated.

Agricultural Chemistry has, in the present day, attained a prominent position. Eminent chemists of all countries are directing their investigations more fully to develop the *science* of agriculture, and as this must result in the propounding of many new theories of inestimable value, it is of the last importance to the farmer that he should become enlightened on the general principles of Agricultural Chemistry, in order to be prepared to take advantage of each as they are given to the world.

II.—ON THE ELEMENTARY COMPOSITION OF ORGANIC BODIES.

THE researches of chemical philosophers have shown us that all substances in nature—mineral, vegetable, or animal—are composed of one or more, out of about sixty-three elementary, or simple bodies. Of these elements one-half are so rare that they are to be found but in a few minerals; and so far as we are able to judge, they appear to play a very insignificant part in the economy of nature. Of the remaining half a considerable number occurs, in comparatively small quantities, so that after all but a very limited number of elements are employed by nature in the production of her rich and varied fabrications: thus, surprising as it may seem, it is nevertheless true, that more than two-thirds of the mineral crust of the planet on which we live are composed of but two elements, oxygen and silicium; and that eight out of every nine tons of the water in our rivers, lakes, and oceans are composed of oxygen alone. Nor is this paucity in the number of materials confined to the mineral world, for chemical analysis has demonstrated that four elements form by far the greater portion of the multitudinous animal and vegetable substances with which we are surrounded. These elements are OXYGEN, HYDROGEN, CARBON, and NITROGEN, two or more of which, combined in various proportions, produce an almost infinite variety of proximate principles. A few other elements are found in organic (animal and vegetable) bodies, but usually in small quantity, and in many instances they are altogether wanting.

The elements entering into the composition of animal and vegetable structures may be conveniently divided into two classes: first, OXYGEN, NITROGEN, HYDROGEN, and CARBON, forming the combustible portion of organic bodies; these are

sometimes termed the "organic elements," from the circumstance of their composing almost exclusively organic structures. Second, CHLORINE, BROMINE, FLUORINE, IODINE, PHOSPHORUS, SULPHUR, POTASSIUM, SODIUM, CALCIUM, MAGNESIUM, IRON, and MANGANESE, forming the incombustible, or inorganic constituents of vegetable or animal substances.

The *organic* elements are found existing naturally in combination under the form of three well-known substances—namely, carbonic acid, water, and ammonia.

Carbonic acid, water, and ammonia may be termed *the food of plants;* they are the crude materials of which all vegetable fabrics are built, and they exist in the atmosphere in small but sufficient quantity to minister to the wants of vegetable life.

We are indebted to chemistry for our knowledge of the composition of the vast aerial ocean in which we exist, and of its intimate connection with every living being on the surface of the earth. The following may be regarded as the average composition of the atmosphere:—

	By volume.	By weight.
Oxygen	20·55	22·76
Nitrogen	78·16	76·15
Carbonic acid . . .	0·04	0·06
Vapour of water . .	1·25	1·03
	100·00	100·00

Carbonic acid and ammonia are very soluble in water, hence every shower of rain conveys them to the roots of plants, and every breeze wafts them to their expanded leaves.

Although the quantity of carbonic acid in the atmosphere appears relatively small, yet absolutely it is very great—so considerable that were it collected over the earth's surface, it would form a stratum of pure gas, nearly twenty feet in depth. By chemical analysis carbonic acid is found to consist of six

parts by weight of carbon, and sixteen parts by weight of oxygen, so that the weight of carbon in the air, pressing upon each acre of land, is above six tons. The total quantity of carbon in the air, available for the use of plants, has been estimated at 3,300 billions of pounds—a quantity sufficient to supply the wants of the most luxuriant vegetation. Carbonic acid gas is abundantly produced by the combustion of our fuel, and also by the respiration of animals. It exists naturally in combination with lime, forming carbonate of lime or limestone, from which it can be liberated by calcination. Soda water, ale, champagne, and many other beverages owe their pungency and sparkling brilliancy to the presence of this gas.

The following Table exhibits the average elementary composition of several of the more important vegetable substances: 100 parts contain—

Name of Substances.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Water.	Ashes.
Clover Hay	37·3	3·8	30 0	2·0	21·0	5·9
Jerusalem Artichokes ...	9·1	1·1	9·1	0·3	79·3	1·2
Mangel-wurzel	5·2	0·8	5·2	0·2	87·8	0·8
Oats	40·1	5·1	29·1	1·8	20·8	3·1
Oat Straw	35·7	3·9	27·8	0·3	28·7	3·6
Peas	42·5	5·7	36·6	3 8	8·6	2 8
Pea Straw	40·3	4·5	31·4	2·0	11·8	10·0
Potatoes (tuber)	10·6	1·4	10 8	0·3	75·9	1·0
Rye	39·1	4·8	36·0	1·5	16·6	2·0
Rye Straw	40·6	4·6	33·0	0·2	18 7	2·9
Turnips	3·2	0·4	3·2	0·1	92·5	0·6
Wheat (grain)	39·4	5·0	37·1	3·0	14·5	2·0
Wheat (straw)	35·8	3·9	28·8	0·3	26·0	5·2
Wheat Starch	43·5	6·8	49·7	——	——	——
Lignine, or wood	50·0	5·0	42·0	——	——	3·0

III.—ON THE NUTRIMENT OF PLANTS.

I.—ASSIMILATION OF CARBON.

It is now a familiar fact to every intelligent cultivator of the soil, that under the quickening influence of the sunbeam the growing plant absorbs into its pores carbonic acid gas from the surrounding atmosphere. By a mysterious process which takes place within the vegetable structure, the carbonic acid becomes decomposed into its elementary constituents—carbon and oxygen. The oxygen is restored to the air in a pure state, whilst the carbon, combining with the elements of water, or of ammonia, is retained by the plant to form its various tissues.

It has been experimentally proved that the green portions alone of plants absorb carbonic acid gas from the air; the stamens, petals, coloured fruits, and many coloured leaves on the contrary absorb oxygen gas, and eliminate carbonic acid. There are, however, some exceptions to this rule; as an instance, the red leaved spinach absorbs and decomposes as much carbonic acid gas as the green leaved variety of the same plant.

The stimulus of solar light appears to be essentially necessary for the decomposition of carbonic acid by plants, and, consequently, for their healthy development.

During dark, cloudy days the growth of plants proceeds much less rapidly than when they are exposed to the direct rays of the sun; and it has been fully proved that the most brilliant artificial light can never perform the part of the solar beams towards plants. No doubt, under certain circumstances, some varieties of plants may be caused to vegetate in darkness, but they are always found to be unhealthy and destitute

of colour. Such plants, on exposure to light, become green, owing to the formation of chlorophyll, the green colouring matter of vegetables.

Plants do not absorb carbonic acid from the air in darkness, or during the night; on the contrary, they eliminate this gas and absorb oxygen; but their loss of carbon throughout the absence of light is by no means equivalent to their gain of that element whilst under the solar influence. Hence the growth of many kinds of plants will proceed even in winter, notwithstanding the length of the nights; but it must strike the most casual observer of nature's operations how poor is the progress contrasted with that of the period assigned by the Creator for their perfect development—the spring-time and the summer. At these seasons the buds break forth and the leaves expand. All that has been bleak and barren gives place to beauty and perfection. From the lowly shrub to the lordly oak—all, as their luxuriant foliage bends before the breeze, proclaim that their appointed time has returned, and clearly demonstrate that to the length of days and consequent prolonged stimulus of light are to be mainly attributed the perfectitude of vegetable organization.

It is the opinion of Liebig, and many other distinguished chemists, that carbonic acid is the only source from which the carbon of plants is derived. Among the many strong, almost unanswerable proofs which Liebig advances in support of his favourite theory of the nutriment of plants being wholly derived from inorganic matter, may be mentioned the well-known fact, that many varieties of plants can freely vegetate in the air, if supplied with water, without at all being connected with the ground.

The more abundantly we supply carbonic acid to the growing plants the more rapid, *cæteris paribus*, will be their development. The slow decay of vegetable matter in the soil

gives rise to the formation of carbonic acid, which, dissolving in water, forms the chief nutriment of the growing plants, and is taken up by their roots, which, at the early stage of their growth, perform for them the functions of leaves. The production of carbonic acid is considerably promoted by loosening the soil, so as to allow the free access of air without which the oxidation, or decay, of the organic matter present could not proceed.

II.—ASSIMILATION OF HYDROGEN.

The hydrogen required for the formation of vegetable tissues is obtained from water, and, perhaps, sometimes from ammonia; hence we see why the former is so necessary to vegetable life. Water is a compound of hydrogen and oxygen, and we may either suppose that it combines directly with the carbon which the plant has derived from carbonic acid to form the various tissues and products, such as lignine, starch, &c., or that the water is decomposed—its hydrogen combined with the carbonic acid and its oxygen liberated. One hundred parts of carbonic acid and eight parts of hydrogen will nearly give the formula of the composition of woody fibre.

In the formation of many valuable productions, such as turpentine, India rubber, &c., water is undoubtedly decomposed, as these substances are altogether destitute of oxygen, and must, therefore, be formed of the carbon of the carbonic acid and the hydrogen of the water, the oxygen of both being liberated.

The oxygen required by plants is derived from water or carbonic acid, and sometimes from both.

III.—ASSIMILATION OF NITROGEN.

Carbon, hydrogen, and oxygen constitute by far the greater portion of vegetable substances. Nitrogen does not enter

largely into the composition of plants in their natural state, but such as are cultivated for the purpose of being used as food for man, and some of the inferior animals, must contain a considerable proportion of this element. The value of such plants as food is, indeed, in a great measure, proportionate to the quantity of nitrogen they contain.

From the researches of Baron Liebig, and other eminent investigators in this department of science, it would appear that plants have not the power of directly assimilating nitrogen from the atmosphere; and that ammonia, a compound to which I have already alluded, is the source from which their supply of this element is derived. There are some chemists, however, who believe and have, by experiment, endeavoured to prove, that vegetables directly assimilate the nitrogen of the atmosphere. It has also been urged that plants must originally have derived their nitrogen from that source, as it is believed by most chemists that ammonia is naturally produced only by the decomposition of vegetable and animal substances. It is, however, quite possible that ammonia may be produced by some other operation in nature's chemistry with which we are as yet unacquainted.

Ammonia, when uncombined with other bodies, is a gaseous substance, formed by the union of one chemical proportional (equivalent), or fourteen parts by weight of nitrogen, with three chemical proportionals, or three parts by weight of hydrogen. It possesses a peculiar pungent odor, which we familiarly recognise in hartshorn and smelling salts. During the putrefaction or decay of animal and vegetable substances ammonia is abundantly formed, and passes into the atmosphere. De Saussure was the first to *surmise* its existence in the atmosphere, but Liebig *proved* it by evaporating rain water with a little muriatic acid, for the purpose of fixing the ammonia, and then applying the appropriate tests. The

ammonia obtained from rain water is distinguished by a fœtid animal odor which clearly indicates its origin. Since Liebig's first experiment many others have been made which conclusively prove ammonia to be constantly present in the atmosphere, and attempts have been made to determine even its actual quantity. A very considerable quantity of ammonia is carried down into the soil by rain water, in combination with carbonic and nitric acids; this latter acid being very frequently found in rain water, and more particularly after electrical disturbances in the atmosphere. The dew also furnishes the soil with a large quota of ammonia.

The principal use of gypsum (sulphate of lime) in its agricultural application appears to be the fixing of the ammonia in the soil. Ammonia exists in the air chiefly as a carbonate, and in this state is carried down by rain to the soil, where, meeting with sulphate of lime, a double decomposition—to use a chemical term—takes place, resulting in the formation of two new compounds—sulphate of ammonia and carbonate of lime—the sulphate, unlike the carbonate, is not a vaporous substance.

The quantity of ammonia carried into the soil by rain does not appear to be sufficient to furnish the entire quantity of nitrogen required by rich cereal crops. Many varieties of agricultural plants are capable of eliminating a larger quantity of this element than is naturally supplied to them; at the same time, it must be borne in mind that the free use of highly nitrogenous manure not unfrequently produces a too great luxuriance of the leaves at the expense of the root or seed. Cereal crops, above all others, require the application of nitrogenous manures; indeed, the quantity of nitrogen in such crops depends very much upon the quantity of that element supplied to them in the manure. Thus, a specimen of wheat grown upon a soil well manured with good guano has been

known to yield more than three times the quantity of nitrogen afforded by a specimen selected from a crop which was the produce of a soil manured by cow-dung—a substance which contains but a very small proportion of nitrogen.

The quantity of ammonia present in most soils appears so very great that it is astonishing we should, under any circumstances, require to employ nitrogenous manures. Doctor Krocker, a German chemist, undertook, some years since, an extensive series of experiments, with the view of determining the quantity of ammonia contained in soils. Some of the results at which he arrived are shown in the following tabulated statement:—

SUBSTANCES EXAMINED.	Specific gravity.	Quantity of ammonia in 100 parts of soil dried in the air.
Clayey soil before manuring	2·39	0·170
Clayey soil	2·42	0·163
Disintegrated mould from Hohenheim	2·40	0·156
Subsoil from the same field	2·41	0·104
Clayey soil before manuring	2·41	0·149
Clayey soil before manuring	2·41	0.147
Soil prepared for barley	2·44	0·143
Clayey soil before manuring	2·41	0·139
Loamy soil	2·45	0·135
Loamy soil	2·45	0·133
Soil from America never manured	2·18	0·116
Sandy soil never cultivated	2·50	0·096
Loamy earth dug up from some depth	2·50	0·088
Sandy soil never cultivated	2·51	0·056
Almost pure sand	2·61	0·031
Marls	2·42	0·0988 0·0955 0·0768 0·0736 0·0579 0·0077 0·0047

IV.—ON THE CONNECTION AND HARMONY EXISTING BETWEEN THE MINERAL, VEGETABLE, AND ANIMAL KINGDOMS.

THERE is scarcely anything in nature more beautiful than the harmony and close connection which exist between the vegetable and animal kingdoms. The more we investigate this subject, the more forcibly are we struck by the complete reciprocity which subsists between the two. Animals are entirely dependant upon vegetables for their supply of food or of matter for the nourishment of their bodies. We have abundant reason to believe that the most insignificant and least perfectly organised animals, even those wondrously minute animalculæ, whose existence is only revealed to the human eye by the aid of the microscope, are incapable of directly assimilating inorganic or mineral matter to repair the waste of their systems. Plants may, therefore, be regarded as stationary mechanisms, designed by the CREATOR to elaborate from inorganic matter substances capable of being used as food for animals. It is plain, then, that the existence of animals, independently of vegetables, is an impossibility. Nor is vegetable life uninfluenced by animals. We will see, in the course of our investigations, that both are as intimately connected as life and breath.

The leaves of plants perform precisely the same functions as the lungs of animals; and by an exquisite arrangement of Providence these latter breathe out exactly the gas which the former inhale to sustain their vitality—that is to say, during the process of respiration animals are continuously giving off carbonic acid gas from their lungs, as the refuse of their systems; and carbonic acid, it will be borne in mind, forms the greater portion of the *food of plants*.

It has been estimated that on the average a healthy man

throws out from his lungs, or excretes from the surface of his body, about 37 ounces of carbonic acid gas, or in volume 22 cubic feet, in the twenty-four hours.* From this calculation the population of Dublin, amounting to near 300,000, men, women, and children, alone, must daily yield to the atmosphere more than four hundred thousand pounds of carbonic acid. Nor is respiration the only source of carbonic acid gas, for it is formed in much larger quantities by the combustion of our fuel. In all manufactories where coal or wood is consumed, from the domestic fire as well as from every process by which we obtain artificial light and heat, carbonic acid is unceasingly produced.

Carbonic acid gas, so essential to the vitality of vegetables, is eminently injurious to animal life. Whenever a number of persons congregate in a room the atmosphere becomes oppressive and unwholesome, unless proper arrangements for thorough ventilation have been made; this is chiefly attributable to the amount of carbonic acid which has been given forth from the lungs, and surfaces of the bodies of the persons assembled.

The elements of nature never weary—her operations proceed with a precision and regularity that proclaim the wisdom of the great First Cause. Animals are continually inhaling oxygen gas from the atmosphere, which they combine with the carbon of their worn out tissues, and breathe forth both, under the form of carbonic acid gas, *the food of plants*. Vegetables are continually engaged in absorbing this carbonic acid gas, which they decompose, fixing its carbon and restoring the oxygen to the air. Thus, what is poison to the animal is food to the plant, and what one expires is inspired by the other.

* Liebig, from his observations made upon a number of soldiers, estimates that a vigorous, well fed man excretes daily from his body 49 ounces of carbonic acid; this is a high estimate.

The changes which take place between the two great classes of living beings, as set forth in the annexed table, will afford an illustration of their dependance upon each other, and of the perfection of the divine intelligence which decreed them.

PLANTS		ANIMALS	
Convert . .	CARBON, HYDROGEN, OXYGEN, NITROGEN,	Reorganize . .	CARBON, HYDROGEN, OXYGEN, NITROGEN,
From their *mineral* condition of	Carbonic acid gas, water, and ammonia;	From their condition as vegetable substances, such as starch, &c.;	To the condition of animal substances, as fibrine, fat, &c.;
To the *organic* condition of	Vegetable substances, as starch, sugar, albumen, oil, &c.	And then disorganize and reduce them to their natural *mineral* condition of	Carbonic acid gas, water, and ammonia.

From a consideration of the above table, we clearly perceive how beautiful are the operations of nature's chemistry, and how indispensable an element are plants in the condition of the sustenance of animal life. A great proportion of the animal races consume exclusively vegetable food, which supply the elements necessary for the renovation of their systems. Herbiverous animals thus derive bone, blood, and muscle from the elements of vegetable food, and they, in turn, serve to supply food to the carnivorous tribes, and both carnivorous and herbiverous animals return the elements which they have directly or indirectly received from the vegetable kingdom to the atmosphere, whence they were originally obtained by the plants.

The dependance of the animal and vegetable on the mineral kingdom is a consideration demanding the strictest attention of those who make the philosophy of creation their study.

The solid crust of the earth yields many of the constituents essential for the sustenance and growth both of plants and animals; indeed, the connection between the mineral and vegetable kingdoms forms the basis of agriculture, both as an art and a science.

Animal, vegetable, and mineral kingdoms—these three form the chain by which nature is bound together; the mechanism of each link is so admirable as to evidence unmistakably the skill of the great Designer of all.

The elements of nature are continuously in action, imperceptible to the eye, but still ever in operation, passing from one domain of nature into another. An animal dies, and by decomposition is resolved into its elementary constituents, which pass into the atmosphere as "thin air," thus journeying from the animal to the mineral kingdom, from which they again enter into the vegetable kingdom, and thus the same atoms may again and again have entered into the composition of organic beings.

Investigation into the connection subsisting between the vegetable and animal kingdoms cannot but excite our wonder and reverence at the Omnipotence which pervades all nature, and give rise to reflections that cannot but be salutary and improving.

Man, "the paragon of animals," even as his subjects in creation, "must shuffle off his mortal coil," and commingle in a common dissolution. "We come like shadows, so depart." The very dust which clings to our feet as we pass through the grave yard was once invested with life. Surely the poet did not reason unphilosophically when he wrote—Might we not trace the noble dust of Alexander until we found it stopping a bung hole, or that of Cæsar's until it served to stop a flaw to keep the winter's wind away. Here, however, the analogy between man and the inferior animal ceases. The breath

within his nostrils returns to HIM who gave it. Nature's task is ended. Revelation here must take the story up.

The same commingling in a common dissolution also prevails in the vegetable creation. The towering oak and the creeping briar must meet an equal doom. The majestic forest, even as the grass, "withereth away." Age succeeds age, resuscitation succeeds decay, and thus to us the world is presented ever dressed in pristine freshness. It is part of our mission to preserve and add to its adornment. Beautifully has it been said that the earth is a kind mother to us. She receives us when we are born, sustains and nourishes us whilst living, and takes us into her bosom when dead.

To conclude—investigation into science must be productive of the most beneficial results, not merely as regards the getting of our "daily bread," but, also, as administering food the most grateful to the intellect, it is powerfully instrumental in exalting, ennobling, and expanding the mind. Science stands ready with her lamp to enlighten the understanding, and upon what mind has a gleam once fallen that was not led

"To look from nature up to nature's God."

The intelligence which is illumined by this light will discover in the way-side flower a perfection in design and beauty in construction which cannot fail to convince it that flowers are kisses impressed by heaven upon the earth. This light will also reveal in the organization of the minutest insect, imperceptible though it be to the unassisted eye, more to awaken admiration towards the CREATOR than caused the untutored savage to make the sun his god!

Let science once take up her abode in the "dome of thought—the temple of the mind," she must exist "unmixed with baser matter."

V.—ON THE ROTATION OF CROPS.

EXPERIENCE has made known to us the fact, that plants of the same kind do not thrive for several consecutive years on the same soil, and under the usual treatment; for, however fertile the soil may naturally be, a time will arrive, sooner or later, when it will become unproductive, and even cease to return the seed. Such a soil will then require to remain uncultivated for a certain period, until the influence of time restores it in some degree to a fertile condition. During the period of its renovation the land is said to lie *fallow*. Of this mode of restoring fertility to an exhausted soil, Sir Robert Kane truly remarks—"It is a method synonymous with an ignorant and improvident agriculture."

The necessity of allowing the land to lie idle every third or fourth year has been altogether obviated by the introduction of the system of the rotation, or alternation of crops—a system which has given to agriculture the greatest impetus it has yet received, and has increased to a very considerable degree the produce of the country.* The principles upon which this system is based are as follow:—

* The incalculable advantages flowing from a judicious system of rotation cropping is strikingly exemplified in the following article extracted from M'Cullogh's "*Statistical Account of the British Empire*," in which a contrast is presented between the improved mode of cultivating the soil, based on the system of the rotation of crops, adopted in the Lothians, a highly cultivated district in Scotland, with the unproductive mode which prevailed there seventy or eighty years ago:—

"The old mode of cropping was—first, peas; second, wheat; third, barley; fourth, oats; the produce being about three seeds, but, to prevent all cavil, say four seeds. This, taking the seed for each acre at one boll (i. e., six bushels), over a farm of 100 acres is 400 bolls. The quantity of straw for each boll, of such a crop, could not exceed 15 stones, which, on 400 bolls, gives 6,000 stones, or 42 tons, 15¼ cwt. of straw, to be consumed by the stock, and returned to the land in the

First—*Every plant removes from the soil a certain quantity of soluble materials.*

Second—*All varieties of plants do not take from the soil the same quantity of materials.*

shape of manure. But, upon a farm of 100 acres, cultivated as at present—namely, a fourth, turnips; a fourth, wheat or barley; a fourth, clover and rye-grass, pastured or made into hay, and consumed on the farm; and a fourth, oats or wheat—the account would stand thus: 50 acres of wheat, barley, and oats, at eight bolls per acre, which, we are convinced, is not above the average crops of the best district of East Lothian (and such only was cultivated at the period referred to), this, allowing, as before, 15 stones of straw for each boll, gives 120 stones per acre, which, over 50 acres, make, in all, 6,000 stones of straw, or 42 tons, 15¼ cwt., being equal to the quantity produced by the whole 100 acres under the old system. Now, supposing that the 25 acres of clover and rye-grass are made into hay (which, however, is not the mode always practised, nor the best mode of obtaining the greatest quantity of manure, and keeping up the fertility of the soil), and that each acre yields 200 stones, the total quantity will be 5,000 stones, or 25 tons, 14 one-tenth cwt.; and add to this 500 tons of turnips, being the produce of 25 acres, at 20 tons per acre, which is, by no means, above a fair average crop. Upon these data, the weight of materials produced annually for manure, under the old and new systems, will be as follows:—

Old System—	Straw,	6,000 stones—	42 tons,	15¼ cwt.	
New system—	Straw,	6,000 „	42 „	15¼ „	
	Hay,	5,000 „	35 „	14 1-10th cwt.	
	Turnips,	70,000 „	500 „	—	

Thus making the weight of materials to be converted into manure, under the new system, in round numbers, 577 tons; while under the old system, the quantity is only 42 tons, leaving a balance in favour of the new system of 533 tons per annum, being *more than twelve times the whole quantity produced under the old.* Nothing more is necessary to show the superiority of the new system, in so far as *keeping up the fertility of the soil* is concerned; and upon this depends the progress of agriculture. And as to the question of comparative profit, it would be easy to show, from unquestionable data, that the new system is as superior to the old, in this respect, as it is in the supply of manure; but this, we think, must be abundantly obvious to every one who contrasts the almost imperceptible advances made in agriculture, and in the accumulation of agricultural capital, for many centuries, with their extraordinary progress during the last seventy years, or since the new system was introduced."

Third—*All varieties of plants do not extract from the soil the same kind of materials.*

Fourth—*Each kind of plant differently affects the growth of weeds.*

Bearing these principles in mind, the intelligent agriculturist will see the necessity of the observance of the following excellent rules, as laid down by Professor Hodges:—

I.—"That plants which require *chiefly* the same kind of materials for their support should not be grown in succession."

II.—"That as the effects which different crops produce upon the fertility of the soil are influenced by the purpose for which they are grown, plants cultivated for the sake of their *seeds*, as wheat, barley, oats, flax, should be made to *alternate* with those which are cultivated for their *roots*, *foliage*, or *fibre*, as turnips, clover, &c., and also hemp and flax, when the seeds are not allowed to ripen."

III.—"That the greatest possible interval should be introduced in the rotation between plants of the same kind, by the growth of as great a variety of crops as the climate of the country will allow; thus, instead of the farmer confining himself to wheat, barley, oats, turnips, potatoes, and clover, he should cultivate beans, peas, vetches, mangel wurzel, carrots, parsnips, beet, flax, hemp, &c."

Crops may be alternated with each other, when each variety extracts from the soil materials of a different kind, or affect the soil differently; thus, wheat removes from the soil much phosphoric acid, for, without that substance, its seeds, which form the "staff of life," could not, by possibility, be produced; leguminous plants, such as peas, beans, &c., on the contrary, require but little phosphoric acid for their development; these, therefore, should be alternated with wheat crops, because, during their growth, a quantity of phosphoric acid which

existed in an insoluble condition in the rocky portion of the soil is rendered soluble, and, therefore, available from the disintegration of the latter, occasioned by the chemical and physical forces which are unceasingly in operation. The entire quantity of phosphoric acid thus rendered available is not required for the development of the peas or beans, as the case may be, and it is therefore allowed to accumulate in the soil, until such time as the farmer may again decide on raising a wheat or other cereal crop.

By the old system of *fallowing*, the land, instead of being devoted to the raising of valuable crops, would be allowed to remain completely idle during the entire period which nature required to repair the damages inflicted on the soil by exhausting crops: what the amount of loss in this country may have been by the system of *fallowing* we cannot calculate, but some idea may be formed of its immensity in France, at one period, when we learn from the agricultural statistics of Eure, a department of France, that in the year 1800 the lands lying fallow (idle) in that department were no less than 172,000 hectares, (a hectare is about $2\frac{1}{2}$ English acres), whilst we may, with satisfaction, gather from the same authority the gratifying intelligence that the progress of enlightenment had, in 1837, reduced that number by more than one-half.

The employing of the land to produce other crops, whilst it is being replenished by nature for the production of that which had previously exhausted it, is an important step in the progress of *scientific* agriculture. Indeed, so far is it from impeding the progress of amelioration just mentioned, that we have reason to believe that the mechanical operations attendant upon the raising of the intermediate crops facilitate this process materially. The breaking up of the super and sub-soils, and exposing them to the action of the air, promote this end.

The roots themselves act mechanically on the soil, and when allowed to remain there, add to its organic matter, and thus contribute greatly to its enrichment.

The introduction of manure into the soil during the period when fallow crops are being raised may accomplish a two-fold object; if ammonia be in the manure, its nitrogen will serve as food for the plants, whilst its salts, as the sulphate, &c., act as solvents of certain important mineral constituents of the soil. In this latter case we perceive that the accumulation of soluble materials in the soil necessary for a return to the first or exhausting crop is facilitated materially by the intervention of what may be applied by human ingenuity. We see, too, that it may be facilitated considerably by means not exactly intended for that purpose, or even known to many farmers to be calculated to produce such a result. These are considerations which, whilst they show the advantage of rotation, indicate also a cause of occasional waste to the cultivator. When, for example, time alone is sufficient for his purpose, and that this time is allowed, it is a waste to add those substances to the soil which aid in the accumulation of soluble mineral matter, if the intermediate or non-exhausting crops can be produced without them; or when it would be to the farmer's advantage to return to the first crop sooner than at the expiration of the usual course, it would be equally wasteful to employ time to do what he could with equal certainty accomplish directly by applying his solvents. Nor is this all; in the first of these two cases he must, at the expiration of the period of rotation, leave in the soil the amount of soluble matter produced by the weathering of its rocky constituents, whilst, in addition to this, he has what the solvents artificially applied, prepared; a double quantity at the end of a single period. The crop takes up one-half, leaving the other. The remaining half, in the pos-

session of one who merely rotates his crops by *rote*, is allowed to lie there perhaps for five or six years, at the end of which period he has, under the operation of similar causes, a threefold amount.

Merely guided by an empirical system, we can now see that a man might go on for any number of years, regularly adding to the soil, increasing its store of soluble materials, at a considerable outlay, without receiving an equivalent return, burying valuable materials where not required, whilst another part of his farm may be languishing for them. Thus, when a farmer applies, say guano, containing 18 or 19 per cent. of ammonia to a field rich in nitrogenous matter, and intended for the growth of turnips, he spends his money in supplying to the soil a costly substance in greater quantity than the turnips require, and which money might be better expended in the purchase of bones, superphosphate of lime, or highly phosphatic guano, which articles, as sources of phosphoric acid, contribute far more to the growth of turnips than ammonia; the turnips, by means of their large leaves, being capable of absorbing nearly all the ammonia they require from the atmosphere.

It is chemistry that points out and explains to us the value and *rationale* of that great step in agriculture, the rotation of crops; and chemistry alone can teach the farmer truthful lessons on the economy of time and manure. In reference to the first of these, it is clearly deducible from what has been said, that there is still great room for improvement in the system of the rotation of crops; that it can never be entirely relied upon in every particular case, without the application of an accurate knowledge of the constitution of the soil at the time being; that in numerous instances this knowledge might enable the farmer to dispense with rotation altogether, and to adapt his supply more directly to the demand in the market,

and to all the economic considerations which go to decide any man as to what article he should produce.

There are many circumstances which may render it advantageous to the farmer to grow a succession of crops of the same kind. In the very article of manure he may find a reason for adopting a course quite different from that which custom dictates to him. Thus, in the neighbourhood of large cities and towns where ammonia exists abundantly in the atmosphere, and where manure may be cheaply obtained, many kinds of crops, and for which there exists an urgent demand, may be raised year after year in succession, provided there be annually restored to the soil as much, or nearly as much, *mineral* matter as the crop of the preceding year had withdrawn from it.

Whilst we must thus regard rotation as a great step in the progress of agriculture, we must view it only as a step towards an end, and not the end itself. As a system the practical farmer will see that great variations in its application will arise out of a wider diffusion of chemical knowledge amongst agriculturists. And the demand which science may be supposed at this point to make upon the cultivators of the soil, who know how to observe the workings of nature around them, is to make known the facts in their experience, and the phenomena which they observe, so that from among the variations just mentioned, we may, ere long, be able to build up of facts a system of cropping which, in agriculture, shall be entitled to rank with those unfailing, because perfectly scientific processes by which manufacturers accomplish their ends.

Having entered at some length into the *science* of the system of the alternation of crops, it remains now but to point out certain rotations which have been very generally and successfully adopted.

The four-shift or "Norfolk" course of cropping extends over a period of four years, and derives its designation from the county in which it originated. It is as follows:—First year, turnips; second year, barley; third year, clover and mixed grass seeds; fourth year, wheat. Of late years oats have been adopted by the Norfolk farmers after the wheat crop of the fourth year, thus extending the course over a period of five years. The four-course system is adopted in most parts of the United Kingdom, and is, in fact, the basis upon which all other courses are founded. In cases of inferior land the course should be extended by one or more years' pasture, followed by oats.

The following five-year course has been recommended as suitable in many cases:—First year, turnips, manured with farm-yard manure together with bones, or superphosphate of lime—a portion of the crop being consumed on the ground by sheep. Second year, potatoes, manured with guano and rape dust. Third year, wheat, grass seeds being sown in spring along with the crop. Fourth year, clover and grass, top-dressed with guano and nitrate of soda. Fifth year, oats. This rotation is worthy of attention, especially in the case of inferior and deteriorated lands.

The East Lothian six-course rotation is arranged in the following order:—1, turnips; 2, wheat or barley; 3, grass; 4, oats; 5, beans or potatoes; 6, wheat.

In Nottinghamshire the following eight-course system is generally adopted:—1, turnips; 2, barley; 3, clover and grass; 4, wheat; 5, mangel wurzel; 6, wheat; 7, beans; 8, wheat. The land is plentifully supplied with manure in the first, fifth, and seventh years of the course, and occasionally the clover and grass in the third year.

A six-course followed in some parts of Yorkshire is—1, swedes; 2, oats, with which grass seeds are sown; 3, clover

and rye-grass, affording pasture for sheep, which receive a daily allowance of oil cake; 4, wheat; 5, white turnips, with sheep on the ground, or rape; 6, wheat.

The following courses of rotation are adapted to the climate of Ireland, and for the description of soils mentioned:—

1. FERTILE LOAMS.	2. LIGHT SOILS.	3. INFERIOR CLAY SOILS.
	First Year.	
Potatoes, turnips, parsnips, mangels, &c.	Turnips, one-half to be consumed on the ground by sheep.	Potatoes, turnips, &c.
	Second Year.	
Wheat.	Oats and barley.	Wheat or oats.
	Third Year.	
Clover and rye-grass.	Clover.	Clover and mixed grass seeds.
	Fourth Year.	
Oats.	Pasture.	Pasture.
	Fifth Year.	
Potatoes or drilled beans.	Ditto.	Oats.
	Sixth Year.	
Wheat.	Oats.	Vetches, peas.
	Seventh Year.	
		Wheat or oats.

VI.—ON THE RELATION BETWEEN THE PLANT AND THE SOIL.

THE chemist puts the agriculturist in possession of such a knowledge of the properties of the various substances necessary to the production of his crops as enables him, in the shortest time and at the least expense, to adapt the kinds and quantities of his produce to the demands in the market, and to the various other circumstances in reference to which economic science directs him.

From the co-operation of the chemist and the farmer, the period may not be very distant when the *science* of agriculture shall be so perfect as to enable the farmer to take stock, from time to time, like any other capitalist, and to carry on his operations in accordance with those great natural laws which alone can secure the greatest advantages at the least expenditure of time and materials. With a correct knowledge of what the various plants require; of what the soil, from time to time, is in need of; and by what means the deficiencies in the latter case may be best and most economically supplied: in short, by a correct knowledge of the relations existing between the plant and the soil in which it grows, there need be no such haphazard attempts in agriculture as, unfortunately, at present but too generally prevail.

These speculations may appear of too visionary a character; but what mighty triumphs has not science achieved! what wonders has it not revealed to us in our own day! The bleacher, by the aid of chemistry, has been enabled to compress the toil and anxiety of months into the brief duration of a few hours. The tanner, too, by its agency, has overcome the tedious ordeal of a twelve-months' process, and can now produce, in a few weeks, an article in all respects equal, if not

superior. Similar advantages await the agriculturist. The question now is, when will he avail himself of them?

What incalculable benefits would result to the community at large, dependant as it is almost entirely upon the produce of the soil, were the husbandman enabled to engage in his avocation with the same, or nearly the same, certainty as the manufacturer can, who understands the nature of the processes, materials, and products of his arts! And why should this not be realized? Why is it, for example, that the bleacher or dyer is able to perform, literally, wonders with such certainty and precision? Simply because he has availed himself of the knowledge which chemistry has placed at his disposal; because the means he employs are those which science not only assures him will produce the effect, but also reveals to him every step in the process—every link in the chain of causation. A knowledge of the conditions which must be observed to produce a healthy blade of grass, or a full ear of corn, is as attainable as that knowledge which has worked such wonders in the printing and dyeing of calico, and in very many others of the industrial arts.

A farmer may find that he can produce one, two, or three kinds of crops, at a moderate cost, whilst it would take an unprofitable outlay to produce a fourth either immediately or at a future period; that his land may be naturally well adapted for a certain class or classes of plants, whilst he is ruining himself to make it suitable for some other kinds. In many extensive districts experience would seem to have decided what crops are best suited to certain lands and climates; thus, for instance, we have one producing nothing but hops, whilst another yields only oats and potatoes. But the very fact that whole districts are thus laid out by *tradition* for certain crops, while the most casual observer may readily perceive that they possess a great variety of soils, furnishes one of the

most conclusive proofs of the necessity of submitting the question to the decision of a more enlightened tribunal. Many of these decisions have been arrived at, not from a careful consideration of the capabilities of the soil, or of its relation to the plants grown in it, but from the pressure of a local and temporary demand. No one would say, for example, that those vast tracts of naturally good land in Lancashire, which at present yield nothing but meadow hay, were designed by nature for the special production of that crop, or that experience had proved that they were best adapted for it. In this particular instance one circumstance determined the original application, without any regard to adaptation, and another conduces to continue it. In the very heart of that great manufacturing district there was nothing more natural than that manufacturing and trading enterprise should engross a very considerable portion of the energy and capital of the locality, leaving the cultivation of the land in the hands of men of small capital and less intelligence, whose husbandry consists chiefly in top-dressing the grass lands and making hay. To this, then, and not to enlightened experience, we may trace the appropriation of the land in question. As plainly can we understand why this system is persevered in. The demand for hay to feed the carriers' horses, and the cows which supply the factory operatives with milk and butter, goes far to preserve the old order of things. Not only does the competent observer thus infer that such an appropriation is anything but what science and economy would sanction; but the occasional instance in which the land is managed on the principles applied to other branches of business in the same locality, furnishes ample proof of the correctness of his reasoning. The farms, for example, of the late Mr. Grant,*

* Of the firm of "Cheeryble Brothers." *Vide* Dickens's *Nicholas Nickleby.*

of Nuttall Hall, of Mr. Knowles, of Tottington, and of some others, to the cultivation of which manufacturing skill and enterprize were brought, are cases in point, and deserve to be mentioned, as most certainly they cannot fail to be noticed, by travellers in that part of England, as forming oases in an otherwise agricultural desert.

There are, no doubt, many instances in which the application of science would show that experience had led to a judicious appropriation of the land; and there are numerous examples of agricultural reformers who, possessing but a "little learning" in such matters, in attempting to overthrow ancient experience, have discovered at once their own ignorance and the bottom of their purses, and were forced to confess that they, instead of being more, were less, enlightened than their predecessors.

The fertility of a soil depends not only upon the presence of certain ingredients, but on the condition in which they exist—a distinction very liable to be overlooked. Thus, a farmer on getting his soil analysed, and learning from such that it (the soil) contains certain valuable substances, but without knowing how many and what quantity of these substances are in an available condition, naturally reasons that having them *there*, he has nothing whatever to do but sow his crops, and take them out. I can easily imagine his disappointment, and the triumph of his *practical* neighbour, who has a *contempt* for science (there are too many of the latter kind of people to be found everywhere), on finding there was not a return commensurate with his expectations. The question of the *condition* in which the desired substances existed had been overlooked, and this having fully as much to do with the produce as the presence of the substances, the semi-enlightened farmer experiences the evil of the "little learning" he has brought to bear on his avocation.

Instances of failure such as these become the chief stumbling blocks on the road to science; but so far from being so they should become stronger incentives to push inquiries further, and by acquiring a more perfect knowledge of science discover the cause of failure. By these means, in the departments of art and science, has perfect success been achieved, and by these means alone can the tiller of the land hope to succeed.

There are few soils which do not contain alkalis and other substances required by plants, in considerable quantities. It will give some idea of the enormous amount of potash existing in aluminous clay, formed by the disintegration of the mineral felspar, to state that the latter substance frequently contains 17 per cent. of potash. Felspar is an abundant constituent of granite, gneiss, and other rocks, and by its decomposition affords soils of a highly fertile character.

From the analysis of certain rocks the quantity of potash contained in the soils, formed by their decomposition, may be readily estimated. Thus, it has been calculated that 26,910 square feet of soil, twenty inches in depth, formed of decomposed

Felspar, contain		.	.	1,269,000	pounds.
Clinkstone	„	from 220,400	to	440,000	„
Basalt	„	„ 52,300	„	882,600	„
Clay-slate	„	„ 100,000	„	220,400	„
Loam	„	„ 95,800	„	330,600	„

There are few soils in Ireland, however, in which the alkalis exist in a soluble condition in any very great quantity, as a succession of crops during a countless number of years has removed all, or nearly all, that was in that available condition; for, although a crop of twenty tons of turnips to the acre will remove from it between the bulbs and tops only about 260 lbs. of alkalis, yet, when we consider that for centuries crop after crop has been taken from the soil without its receiving an equi-

valent in return, we cannot wonder that we now find it necessary to supply the soil liberally with alkalis as well as with other matters which, although present, are bound up securely in its rocky parts. The fertility of the soil thus depending, to a great extent, not merely on the presence of certain materials, but also upon the necessary quantities being present in a *soluble condition*, the analysis of a soil is of little value to the farmer unless it informs him how much of materials, immediately available, he has at his command.

In the newly settled states of North America, the agriculturist felicitates himself with the idea that his soil is endowed with inexhaustible productiveness; for year after year he finds his land to yield, without apparent diminution, rich crops of golden grain, even without the application of manure of any kind. But there can be no question that his soil is all the time becoming deteriorated, and less rich in those soluble ingredients which enable it to yield such luxuriant crops, and that the time though slowly is surely approaching, when, being reduced to absolute sterility, it will require to lie *fallow*, perhaps for ages, until the action of air and water, variations of temperature, &c., shall have further disintegrated its rocky constituents, and rendered available a fresh supply of soluble materials.*

Many districts in Virginia have been reduced to absolute barrenness by a continued and exhausting succession of crops of wheat and tobacco. That the soils of these districts were origi-

* Whole districts in the state of New York which, 70 or 80 years ago, were remarkably fertile, and yielded, *without manuring*, a produce of from 12 to 16 bushels of wheat per acre, now give only from 2½ to 4 bushels. Nor is this deteriorating system of agriculture confined in its worst features to the state of New York; a similar diminution of the productiveness of the soil is observed in *every* other state of the Union where the land has been cultivated or rather *robbed* for a lengthened period.

nally of the most fertile character is abundantly evidenced by the fact, that in the space of a century no less than 13,200 lbs. of alkalis per acre were removed in the crops, without a single pound having been returned in the form of manure. There is in this removal of the fertilizing constituents of the soil a *go-a-head-iveness*, but in the wrong direction, which many will regard as being peculiarly American in its character. But unfortunately there are not wanting in our own country numerous examples of as reckless waste and ignorant management. There are men living who recollect when it was not an uncommon circumstance for farmers to cart their manure to the sea side to be washed away by the waves!

Notwithstanding the gloomy aspect which American* husbandry in general presents, and of the lack of knowledge on the subject of scientific agriculture which too generally prevails in our own country, we cannot say that agriculture is stationary; on the contrary, vast improvements have of late taken place in the modes of cultivating the land, and have been attended with great benefit to the community at large. For this progress agriculture is greatly indebted to chemistry, but much yet remains to be accomplished; and it is to the steady application of the principles of chemical science to the elucidation of the phenomena of vegetation, and to the acquirement of a thorough scientific knowledge of the relations existing between the plant and the soil, that we must look for further improvement.

* I do not mean to assert that there are no intelligent farmers in the United States. There are, no doubt, many who have availed themselves of the light which science has shed on the intricacies of their avocation; but for the one who maintains or exalts the fertility of his farm by the adoption of a scientific system of agriculture, there are seven or eight who are unceasingly engaged in impoverishing their soils, by removing crops from them year after year, without making good the elements of fertility which have been thus abstracted.

"Self love and social are the same." The man who steadily fixes his aim to advance his own interest, even if he willed it, cannot be entirely selfish. He needs help and must give employment. Therefore the higher agriculture attains as a science, the greater will be the benefits conferred upon the human family. Regarded in every light, it is evident that there cannot be too many enlisted in the cause of agricultural progress. Here is a victory to be achieved more glorious than ever warrior won—a triumph over ignorance and stereotyped routine; the subjugation of nature to man's will—once sterile, she will then minister bountifully to his necessities; a triumph certain to bring peace and plenty to every homestead throughout the land. It is a subject possessing the deepest interest for the citizen, the political economist, the statesman, and the philanthropist; for every one whose aspirations are for his country's weal. With abundance come good order and contentment. By an improved system of agriculture, based on scientific principles, this abundance lies within our reach. Let there be but a general adoption of these principles, and Want, with its attendant train of evils, will flee our shores, and, favoured by Providence, "Peace shall dwell within our walls and plenty within our palaces."

As it is of the highest importance to the farmer to know the amount and nature of the inorganic materials which cultivated plants require for their perfect development, I cannot more appropriately conclude this article on the *relation between the plant and the soil* than by showing, in a tabulated form, the *quantities* and *kind* which the soil *must* furnish to some of the more important varieties of our cultivated plants.

The following analyses, which have been recently made, are principally by Way and Ogston, Thornton Herapath, Norton, and Richardson:—

ANALYSES OF THE ASHES OF PLANTS.

Those numbers marked with an asterisk refer to 100 parts of the substance in its natural or undried state; the remaining numbers refer to 100 parts when dried.

	Rape Seed.	Flax.		Peas.	Kidney Beans.	White Turnip Seed.	Turnip Bulb (Swede).	Cucumber.	Mangel Wurzel Seed.	Potatoes (tubers).	Hop Flowers.
		Stalk.	Seed.								
Potash	25·18	34·96	32·55	43·09	36·83	21·91	39·82	47·52	16·08	35·15	19·41
Soda	—	—	2·51	—	18·40	1·23	10·86	—	6·86	5·77	0·70
Lime	12·91	15·87	9·45	4·77	7·75	17·40	12·75	6·31	13·42	2·14	14·15
Magnesia	11·39	3·68	16·23	8·06	6·33	8·74	4·68	4·26	15·22	2·69	5·84
Sesquioxide of Iron	0·62	4·84	0·88	—	2·24	1·95	0·89	—	0·40	1·79	2·41
" Manganese	—	—	—	—	—	—	—	—	—	—	—
Sulphuric Acid	0·53	4·99	1·43	0·44	3·96	7·10	13·15	4·60	3·64	3·29	8·28
Muriatic Acid	0·11	—	—	1·96	—	—	3·68	—	—	—	2·26
Carbonic Acid	2·20	13·39	—	—	—	0·82	—	—	13·85	17·14	11.01
Phosphoric Acid	45·95	8·48	35·99	40·56	11·60	40·17	6·69	18·03	13·35	20·70	14·64
Silica	1·11	5·60	1·46	0·79	4·09	0·67	7·05	7·12	1·86	3·00	18·56
Chloride of Potassium	—	7·65	—	—	—	—	—	4·19	—	1·84	—
Chloride of Sodium	—	0·54	—	—	2·80	—	—	9·06	15·30	6·49	2·95
Total	100·00	100·00	100·00	99·67	100·00	99·99	99·57	100·09	99.98	100·00	99·71
Per-centage of Ash	4·51	5·00	3·05	5·21	0·68 *	3·98	7·60	0·63 *	6·58		6·05

ANALYSES OF THE ASHES OF PLANTS.

Those numbers marked with an asterisk refer to 100 parts of the substance in its natural or undried state; the remaining numbers refer to 100 parts when dried.

	Broccoli.		Cow Cabbage.		Kohl-rabi, from chalk soil.		Wheat (Grain).	Wheat.		Barley.	
	Root.	Leaves.	Leaves.	Stalk.	Leaves.	Tuber.		Grain.	Straw.	Grain.	Straw.
Potash	47·16	22·10	40·86	40·93	9·31	36·27	29·51	25·92	10·78	32·02	14·87
Soda	—	7·55	2·43	4·05	—	2 84	10·61	—	—	1 21	0·28
Lime	4·70	28·44	15·01	10·61	30 31	10·20	0·99	3·80	2·44	3 39	8·50
Magnesia	3·93	3·43	2 39	3·85	3·62	2·36	10·60	12·27	3·23	10·99	1·70
Sesquioxide of Iron	—	—	0·77	0·41	5·50	0·38	—	1·12	0·54	0·15	0·20
,, Manganese	—	—	—	—	—	—	—	—	—	—	—
Sulphuric Acid	10·35	16·10	7·27	11·11	10·63	11·43	0·09	—	1·77	—	2 22
Muriatic Acid	—	—	—	—	—	—	—	—	—	—	—
Carbonic Acid	—	—	16·68	6·33	8·97	10·24	—	4·43	6·01	0·48	1·25
Phosphoric Acid	25·83	19·81	12·52	19·57	9·43	13·46	47·55	43·44	3·69	29·92	4·22
Silica	1·81	2·83	1·66	1·04	9·57	0·82	0·11	7·16	64·84	21·12	62·89
Chloride of Potassium	6·22	—	—	—	5·99	—	—	1·08	3·96	—	—
Chloride of Sodium	a trace	—	—	2·08	6·66	11·90	0·54	—	0·42	0·72	4·37
Total	100·00	100·26	99·99	99·98	99·99	99·90	100·00	99·17	99·68	100·00	100·00
Per-centage of Ash	1·01 *	1·70 *	0·70 *	1·24 *	18·54	8·09	2·32	1·645	5·252	2·22	5·49

ANALYSES OF THE ASHES OF PLANTS.

The number marked with an asterisk refers to 100 parts of the substance in its natural or undried state; the remaining numbers refer to 100 parts when dried.

	Cauli-flowers.	Hopeton Oats (Grain).	Potato Oats (Grain).	Husks of Potato Oats.	Rye.		Hay.	Grasses (in flower).			
					Grain.	Straw.		Bromus erectus.	Lolium perenne.	Annual Rye-grass.	Avena flaves-cens.
Potash	34·39	20·65	31.56	2.23	31·76	17·36	20·80	20·33	24·67	28·99	36·06
Soda	14·79	—		8·97	4·45	0·31	10·85	—	—	0·87	0·73
Lime	2·96	10·28	5·32	4·30	2·92	9·06	8·24	10·38	9 64	6·82	7·98
Magnesia	2·38	7·82	8·69	2·35	10·13	2·41	4·01	4·99	2·85	2·59	3·07
Sesquioxide of Iron	1·69	3·85	0·88	0·32	0·82	1·36	1·83	0·26	0·21	0·28	2·40
,, Manganese	—	0·42	—	—	—	—	—	—	—	—	—
Sulphuric Acid	11·16	—	—	4·30	1·46	0·83	2·11	5·46	5·20	3·45	4·00
Muriatic Acid	—	—	—	—	—	0·46	—	—	—	—	—
Carbonic Acid	—	—	—	—	—	—	0·68	0·55	0·49	—	—
Phosphoric Acid	27·85	50·44	49·19	0·66	47·29	3·82	15·43	7·53	8·73	10·07	9·31
Silica	1·92	4.40	1·87	74·18	0·17	64·50	30·01	38·48	27·13	41·79	35·20
Chloride of Potassium	—	1·03	—	—	—	—	—	10·68	13·80	—	—
Chloride of Sodium	2·86	—	0·35	2·39	—	—	5·09	1·38	7·25	5·11	1·25
Total	100·00	98·89	97·86	99·70	100·00	100·11	99·05	99·99	99·97	99·97	100·00
Per-centage of Ash	0·71 *		2·22		2·30	2·60		5·21	7·54	6·45	5·20

VII.—ON THE IMPROVEMENT OF SOILS.

PERHAPS there is no subject in connection with agriculture which demands more special attention than the improvement of the soil.

Circumstanced as Ireland is, with a large agricultural population of her own, and within a few hours' journey of the manufacturing districts of England, in which millions of human beings daily require the products of the earth, it would appear, that it is, at all events for years to come, Ireland's special mission to supply those wants.

The large demand for agricultural produce has of late years been instrumental in gradually increasing the price of food, and, notwithstanding the free importation of foreign corn, there appears no tendency whatever towards a decrease in prices. In this state of things it is obviously the interest, as well as the imperative duty, of every landholder in the country to extend the area of the soil for cultivation, and to take advantage of every means to ameliorate the condition of impoverished or naturally unproductive soils. The attention of both *scientific* and *practical* men should at once be directed to attain an end, viewed in every aspect, so important. It requires no argument to convince a rational mind that immense gain must accrue to the farmer who will apply himself to call into requisition the waste land lying around him, as well as to increase the fertility of that which he has already under cultivation. Few, indeed, of the farms in this country but would be greatly benefited by the application of scientific skill. Most of them require drains to be made, old fences to be levelled, useless ditches to be filled up, and numerous other improvements to be effected.

In a small work, such as the present, it would be manifestly

impossible to describe the various modes of improving the soil which have been proposed; I shall, however, briefly consider a few, the adoption of which has been attended with the most successful and beneficial results.

I.—DRAINAGE.

The presence of an excess of water in the soil is particularly injurious; it keeps it in a constant state of coldness, the heat of the sun, so indispensable for the vigorous development of our cultivated plants, being uselessly expended in evaporating the stagnant water.

The temperature of dry soils is invariably more elevated than that of those supercharged with moisture.

Heavy, tenacious soils become, by drainage, more open and friable, allow the air to permeate freely through them, and are much more easily and economically worked.

Wet soils favor the growth of aquatic and marsh plants to the exclusion of the cultivated ones, the latter being naturally inhabitants of moderately dry soils.

In soils full of water the organic matter present will not undergo ultimate decomposition, owing to the exclusion of oxygen—the great agent in producing chemical changes. The organic matters of soils consist almost entirely of the remains of plants. If the soil be moderately dry, these are, by slow decay, or as it is scientifically termed *eremacausis*, finally converted into carbonic acid gas and ammonia, which, as has been elsewhere remarked, together with a proper supply of water, constitute the *food of plants*. Thus, the remains of one race of plants form the nutriment of those which are to succeed them. In soils excessively moist the vegetable matter is changed into, and remains, a very insoluble substance, termed *humus*, which, for the purposes of vegetation, is perfectly useless; but by draining, the air is permitted to penetrate the

soil, where it acts upon the humus, converting it into gaseous products, and these, dissolving in the moisture of the soil, are taken up by the roots of plants.

Experience has shown that wet soils require the application of a much larger quantity of manure than dry ones; and that crops grown on too humid land are later in attaining maturity than those raised on drained or naturally dry soils.

Professor WAY's valuable researches have proved that drainage water, owing to the absorbent nature of soils, carries away, with the exception of nitric acid, but little fertilizing matter from the land. The loss of nitric acid is, however, in the case of highly manured lands, very considerable, but it is more than compensated for by the immense advantages flowing from the practice of land drainage. In the case of fields cultivated in the ordinary manner Professor WAY found the loss of nitric acid by drainage to be very trifling, and of ammonia to be almost inappreciable.

II.—MANURING WITH MUD (WARPING).

Taking a hint from the wonderful effects produced on the arid lands of Egypt by the overflowing of the Nile, some intelligent English agriculturists have introduced a mode of improving exhausted or naturally bad soils, termed *warping*, which consists in inundating the land from a neighbouring river during the influx of the tide, and allowing it to dry again during low water. Each tide is thus found to leave a layer of mud on the soil, on an average about the tenth of an inch in thickness. By repeating the process a great number of times, an immense quantity of mud is deposited over the land, often to a depth of three feet, but on the average about eighteen inches.

Thornton J. Herapath has investigated in a very complete manner this method of manuring by mud. He has made

analyses of the river water, of the mud, of the soil manured by the mud, and, finally, of the ashes of the plants grown upon the soil after the application of the mud. The following analyses by this chemist exhibit the composition of the water of the river Trent—No. 1, before its application to the land, and No. 2, on its being run off on the completion of the operation:—

		Grains in a Gallon.	
		1	2
Soluble Portion.	Chloride of Calcium	trace	0·499
	„ Magnesium	0·592	
	„ Sodium	3·760	4·002
	„ Potassium	0·096	0·107
	Nitrate of Magnesia and Lime	trace	trace
	Crenate and Apocrenate of Lime ...	1·840	2·001
	Extractive matter	1·202	0·261
	Sulphate of Magnesia	0·848	0·712
	„ Soda	1·680	1·321
Insoluble Portion.	Carbonate of Lime	8·240	7·961
	„ Magnesia	1·840	1·550
	Sulphate of Lime	0·304	0·240
	Sesquioxide of Iron*	1·728	2·990
	Alumina*	1 328	
	Phosphate of Sesquioxide of Iron* ...	trace	trace
	Organic matter	0 320	0·411
	Silica	1·200	2·206
	Very minutely divided particles of sand* ...	1·920	
	Total of contents in the filtered water ...	25·898	24·261
	Amount of mud	233·38	23·72

The substances marked thus * are so minutely divided that they pass through the filter.

From the above analyses it would appear that one foot of water in depth deposited 209·66 grains of mud per gallon, or 4½ tons per acre.

The following analyses show—No. 1, the composition of the mud filtered from the water in the laboratory and dried;

No. 2, mud in its natural state deposited in the river Humber, near its estuary; No. 3, dry mud of a middling quality, origin not specified; No. 4, sterile, sandy soil, previous to the application of the mud; No. 5, sandy soil, manured 15 years before, with 11 inches of mud. Specimens Nos. 4 and 5 were air-dried. The analyses gave in 100 parts:—

	1	2	3	4	5
Water	—	47·49	—	1·06	2·00
Organic matter	7·00	5 94	6·93	2·20	7·61
Chloride of Calcium	—	—	—		
„ Magnesium	—		0·10		
„ Sodium	—		0·94	0·14	0·16
„ Potassium	—	1·66			
Sulphate of Soda	—		0·31		
„ Magnesia	—		1·18		
„ Lime	trace	trace	1·10	trace	trace
Carbonate of Magnesia	1·52	2·60	0·31	trace	0 29
„ Lime	9·77	3·59	8·18	trace	0·46
Potassa and Soda	0·08	0·18	0·47	trace	0·17
Magnesia...	2·68	1·69	2·60	trace	0·26
Lime	0·90	0·39	0·68	trace	0·14
Sesquioxide of Iron	4·46	6·63*	5·05	0·28	1·17
„ Manganese ...	trace	trace	trace	trace	trace
Alumina	4·49	—	8·18	0·39	0·41
Phosphate of sesquioxide of iron ...	0·09	0·58	1·04	trace	0·28
Silica	68·78	—	9·05	0·14	2·77
Sand		29·15	55·87	98·87	83·57
Stones	—	—	—	2·04	1·40

* With Alumina.

The results of Herapath's investigations are extremely interesting and important. For instance, we learn from his calculations, that the quantity of phosphoric acid deposited in the mud on a certain field, amounted to no less a quantity than 17,000 lbs., whilst a crop of wheat, grown on the same field, abstracted but 53 lbs. of this substance. From this may be inferred the great fertilizing powers of mud manure, and it fully accounts for the improvements which it is known to have effected when applied to even remarkably sterile land.

III.—IMPROVEMENT OF SOILS BY LIMING.

The value of lime as a manure has been known from an early age, but until chemical science pointed out its true properties, its functions were misapprehended by farmers. It was considered and styled a stimulant—something which excited for a time the powers of the soil, without being absolutely necessary to the perfect formation of plants. This view of the case is now proved to be erroneous, and the use of lime in agriculture, instead of being, to a great extent, empirical, as was formerly the case, is now guided by a juster appreciation of its value, and of the offices which it performs in promoting vegetation.

The action of lime is two-fold; first, physical, and second, chemical. As a mechanical agent, it opens stiff clays, rendering them friable, mellow, and more easily worked; chemically, it acts upon the vegetable matter in the soil, and sets free those stores of valuable substances which, without the action of this agent, must have remained inert and useless. It also enters directly into the composition of plants, and in many varieties forms a large proportion of the weight of their inorganic constituents. It neutralizes certain acids which are often present in soils, rendering them useful to vegetation, instead of being positively injurious, which they are in their original state. The existence of water in the soil, however, affects the action of lime very considerably. If the land is wet and undrained, lime will not exert the same influence which it would do in the case of thorough drained land. A greater quantity of lime is necessary to produce a given effect, and thus the neglect of thorough drainage entails a considerably greater expenditure in liming than would be necessary, were the land either naturally or artificially dry.

When we take limestone from the quarry, it is not pure

lime. It consists chiefly of carbonate of lime—formed by the combination of carbonic acid and lime—with a variable proportion of earthy matters; and when carbonate of lime or limestone is burned, the carbonic acid is driven off by the heat, and the lime is then termed shell or quick-lime. When water is poured over this burned or quick-lime, great heat is evolved, the lime increases considerably in bulk, absorbing the water, with which it enters into chemical combination, and finally crumbles down into a fine powder. In this state it is somewhat milder than it was previous to the addition of the water, and is called slaked lime, or in chemical *parlance*, hydrate of lime. Quick-lime exposed to the air gradually slakes, owing to its absorption of hygroscopic or atmospheric moisture; but, at the same time, it also absorbs carbonic acid, and thus it becomes partly a hydrate possessing caustic properties, and partly a carbonate or mild lime; and into this latter state it is entirely changed when long exposed to the air, or incorporated with the soil.

In certain districts magnesia enters largely into the composition of limestone; some varieties containing only from one to two, or three per cent. of magnesia, whilst others contain so much as from forty to forty-five per cent.* The presence of magnesia in small quantity does not detract from the agronomic value of lime; when, however, it amounts to nearly one-half the weight of the limestone it becomes injurious, inasmuch as, on being slaked, it becomes a hydrate of magnesia, which sets or hardens under water, or in a wet soil, and forms a perfect cement.

Marls, shell and coral sands, and limestone gravel, owe their effects chiefly to the amount of carbonate of lime which they contain. In marl it is very different in different samples,

* Dolomite is a geological term for magnesian limestone.

some varieties containing as low as five per cent., whilst others contain fully ninety per cent. of carbonate of lime. Such being the case, it is evidently impossible to lay down special rules, applicable, in every instance, where marl is an obtainable manure. The obvious plan is to subject specimens from each marl deposit to a strict chemical analysis, in order that its constituents and consequent value may be ascertained.

Shell and coral sands are frequently met with on different parts of the coasts of these islands, and the most beneficial effects follow the application of these to poor, heathy land. The heath disappears and its place is occupied by a beautiful and spontaneous growth of white clover. Shell-sand contains from thirty to seventy per cent. of carbonate of lime, the remainder being chiefly common silicious sand.

Of limestone gravels we have extensive accumulations, as might be expected, from the large extent of limestone which forms the prevailing rock formation in Ireland. The application of limestone gravel is most efficacious in the reclamation of bog, and thus while we have the evil, we are, at the same time, amply supplied with the remedy. Carbonate of lime constitutes a large proportion of Irish limestone gravels.

Chalk, of which carbonate of lime forms the basis, is extensively used in England. The chalk is dug from pits, and after exposure to the winter's frost, it crumbles down, and in this state it is applied to the land in spring. It may appear strange, that to soils resting on the chalk formation, repeated dressings of chalk should be necessary to ensure their fertility; yet, such is the case, the upper soils being frequently found almost destitute of this important constituent, although the under-lying rock is a mass of carbonate of lime.

The quantity of shell or quick-lime which ought to be

applied to land depends upon the nature of the soil. If lime has not been previously applied, or if a considerable time had elapsed since it was used, then, as the soil may be supposed to be *sick*, a full *dose* must be given, followed by the application of small quantities once during the course of each rotation. From 160 to 300 bushels of quick-lime per statute acre may be used as a primary dressing on medium or stiff soils, whilst light lands will not require more than from seventy to eighty bushels. There is great danger in the too free use of lime, as it renders the land over loose. In such cases oats will not thrive, even when grown on old lea; the braird will come up promising enough, but it will die away about June. Consolidation by means of heavy rollers, by allowing sheep, to eat off the turnips on the ground, and by heavy applications of road scrapings, will tend to remove the effects of over-liming, whilst a fresh application of lime in the compost form will also be generally judicious, because, although such soils are suffering from the physical effects of a too free use of lime, still the surface soil will generally be found nearly destitute of it.

IV.—MIXING OF SOILS.

The benefits derivable from the mixing of different kinds of soils have but little attracted the attention of agriculturists. How many of our waste heaths, bogs, and commons, could be rendered fertile by supplying them with substances of which they are deficient, but which may be found abundantly in soils in their immediate neighbourhood! It is well known that bog land may be rendered productive by the simple addition of lime, or even loamy clay, and that *sterile* clay is rendered fertile by the addition of *barren* sand.

There are few things of which I have a more vivid recollection than of a gravelly slope which, instead of affording any advantage whatever to the owner, formed an eye-sore to

the beholder. At the foot of this slope was a piece of ground which might be regarded as a sort of compromise between a thin bog and a shallow pool studded with little islands of turf. The road to the farm, of which the gravel slope formed a part, was through this marshy land, and it may easily be imagined to have been anything but healthful in summer or agreeable of a winter's night. By a change in the ownership of the land, the bog and slope, which before were owned by two persons, came into the possession of one. There was a drain made to carry away the stagnant and unwholesome water, with a view of laying down the whole of this seemingly useless space, so as to form—if not pasture, at least an enclosure for cattle. It was also ploughed from end to end, and the usual treatment in such cases adopted. During the process of improvement a portion of the gravel was dragged down the hill to the bog, and a quantity of the bog up the hill, by which bog and gravel became thoroughly mixed. The result was, that instead of this field being laid down, as was at first contemplated, it became one of the best and most productive in the whole neighbourhood.

Facts such as I have just detailed help to assure the practical man of what the chemist's theory teaches him, that in a vast number of instances the initiative, at least, in changing a worthless desert into a productive garden, would be the mixing of soils previously lying waste. The practicability of this must be obvious to every man who chooses to think on the subject, and the certainty of success lies simply in the possession and right use of that knowledge of the constitution of the soil which science alone can impart.

There are many districts where soils of different composition lie close to each other, each may be comparatively useless, whilst, by the simple operation of mixing, they are both rendered fertile—one field possessing one set of substances,

whilst another is rich in others. The waggon which carries wealth to the adjoining field brings back therefrom riches of equal value. None are impoverished, but all are enriched by the exchange—a good example of the advantages of free and intelligent commerce.

The mixing of different soils from different fields, as above referred to, is not the only way in which the farmer can turn the knowledge obtained by the analysis of his soils to account in fertilizing his land, and in economising his expenditure in the purchase of manures. In many cases the success of a whole scheme of improvement depends upon the making of wide and deep drains, necessitating the turning up of a great quantity of earth, often from a considerable depth. A chemical analysis of this matter will at once tell whether it would enrich or ameliorate the soil by its being spread over it, or whether, on the contrary, it would prove injurious. If by analysis we learn that the soil brought up from a depth contains a quantity of *soluble* matter, such as is required for the wants of vegetable life, then we can easily perceive that its application would renew the fertility of the field, which, by an exhausting system of cropping, had been deprived of its store of soluble materials; but if, on the other hand, we find it to contain little or no soluble matter, then its application would prove highly injurious to the super-soil, and might render it sterile for years. Thus, we perceive, that an accurate knowledge of the composition of the soil, both sub and super, is absolutely indispensable to the farmer who would carry on his business in an improving and enlightened manner, and with the view of obtaining increased remuneration.*

* For much interesting information relative to the advantages derivable from the mixing of soils, see a paper on the subject by Mr. John Murdoch, read before the Dublin Chemical Society, and published in the *Irish Farmers' Gazette*, for 25th April, 1857.

VIII.—ON MANURING.

In addition to the combustible or organic portion of plants, they are found to contain certain earthy and saline matters which, though in general in small quantity, must, nevertheless, be regarded as essential constituents of particular parts. These inorganic materials exist in considerable quantity in most soils, but, as has been elsewhere stated, principally in an insoluble condition, and in consequence not immediately available for the growth and sustenance of plants. The quantity of soluble mineral substances in soils long under cultivation is usually so small as to be inadequate to minister to the wants of vegetables designed to become food for man. Hence arises the necessity of supplying the nutrient materials required by such plants under the form of manure.

When the vegetable products of a farm are consumed upon the spot, and the elements of these products having been reorganized into the bodies of animals, become subsequently disorganized and returned to the soil, in such a case, the farm would continue for ever fertile, and not only so, but its fertility would be increased by the gradual *weathering* of the rocky constituents of the soil. But in the usual course of what may be termed commercial farming, the products of the land are, for the most part, sent to be consumed in cities and towns, where, after being disorganised by animals, their elements, instead of being carefully preserved and restored to the land, are, at considerable expense, conveyed to the ocean, and thus lost to us for ever. It follows, then, that it becomes a problem of the last importance to the agriculturist how to maintain unimpaired the fertility of his land, and at the same time send his crops to be consumed at a distance.

The judicious application of manures depends altogether upon a correct knowledge of what substances the crop in-

tended to be grown requires, how many of these substances are contained in the soil, and in what available quantity they exist therein. A soil to be fertile must contain, in sufficient quantities, all the materials necessary for the perfect development of all our cultivated plants. If there be one wanted the soil is unfitted to produce, in a perfect state, any crop requiring that particular substance. Let us, for instance, suppose a soil containing no lime, but abounding in all the other elements essential to its fertility, such a soil would be unable to produce even a poor crop; but by the application of marl, or other substances rich in lime, it would be in a condition to produce the heaviest crops. It is often found that very expensive manures, such as the salts of ammonia, nitrate of soda, &c., totally fail in their application to particular soils, whilst comparatively inexpensive manures, such as marl, gypsum, &c., containing lime in abundance, have produced the most wonderful results. This arises from the circumstance of such soils being destitute of lime; hence the application of manures containing no lime would not be productive of the slightest benefit, whilst the employment of marl, quick-lime, &c., would, by supplying exactly the substance of which the soils were deficient, as a matter of necessity be attended by the most beneficial results.

The most perfect system of manuring a naturally fertile soil, and maintaining its productiveness unimpaired, would be to supply it with as much, or nearly as much, mineral matter as our chemical knowledge shows that it requires for the production of the richest crop possible to be raised from it. In addition to the mineral matter, we should also, in most instances, add substances containing nitrogen. The quantity to be supplied should depend on the nature of the crop, that is, upon its capabilities of absorbing ammonia from the atmosphere. It should, however, be borne in mind, that whilst

many varieties of agricultural plants derive by far the greater portion of their nitrogen from the ammonia of the atmosphere, the supply of inorganic materials requisite for the development of *all* kinds can be obtained by them from the soil alone. In the following table I have arranged, under two heads, the principal manures employed. First, those containing all the substances found in cultivated plants. Second, those which abound in, and are employed to supply plants with, one or two nutrient materials. In each paragraph the most costly article is placed first on the list, and the least expensive last.

I.—GENERAL MANURES, OR THOSE CONTAINING ALL THE SUBSTANCES REQUIRED BY PLANTS.

Guano, vitriolized bones, bones, fish, mixed excrements of animals, farm-yard manure, sewage.

II.—SPECIAL MANURES, OR THOSE CAPABLE OF SUPPLYING ONE OR MORE FERTILIZING MATERIALS.

1.—*Nitrogenous Manures.*

Nitrate of potash, muriate of ammonia, nitrate of soda, sulphate of ammonia, dried blood, woollen rags, hair, horn shavings, shoddy or mill-waste, soot, gas liquor.

2.—*Phosphatic Manures.*

Bone ash, animal charcoal, coprolites, apatite, phosphorite.

3.—*Manures rich in Potash.*

Nitrate of potash, sulphate of potash, wood ashes, pulverized felspar.

4.—*Manures rich in Soda.*

Nitrate of soda, sulphate of soda, ashes of sea weeds, common salt.

5.—*Manures rich in Lime.*

Gypsum, soap-waste, quick-lime, marl, shell sand.

6.—Manures containing Sulphuric Acid.

Sulphate of magnesia, sulphate of iron, gypsum.

7.—Manures rich in Carbon.

Peat, forest leaves, saw dust, mould.

IX.—ON FARM-YARD MANURE.

FARM-YARD manure is composed of the mixed excrements of the domestic animals—the horse, the cow, the pig, &c., together with straw litter and other refuse of the farmstead. Its chemical composition varies very much, depending to a great extent on the care bestowed upon its preservation, and likewise upon the quantity and quality of the food supplied to the animals. The fluid and solid excrements of animals form by far the most valuable portion of the fertilizing constituents of farm-yard manure. If the animals be fed with corn, oil cake, and other highly nutritious descriptions of food, their excrements will be much more valuable than if the food be scanty and poor in quality.

Farm-yard manure was, at one period, and that not very remote, the only fertilizer employed by British agriculturists, and it was then supposed to be capable of supplying in sufficient quantity all the materials requisite for the growth of plants. Chemical science has, however, demonstrated that so long as farmers *send* the produce of their fields to be consumed at a distance, so long will it be necessary for them to *obtain* from a distance substances capable of supplying to their fields those elements which the crops have carried away.

Farm-yard manure, even of the best description, cannot be regarded as a very powerful fertilizer; for although it contains

all the substances found in our cultivated plants, yet they exist therein but in very small quantity. This is evident from its analysis, which shows, that on the average one ton of farm-yard manure contains—

Water	... ...	1680 lbs.
Woody fibre	... ...	880 „
Mineral matter	...	168 „
Nitrogen	... ...	10 „

The fluid excrements of animals are far richer in nitrogen than the solid. The latter, however, contain phosphoric acid—a substance which is generally absent in the urine of domestic animals. In general, farmers give but little attention to the preservation of the urine of their stock, esteeming their dung to be a far more highly fertilizing substance: both, however, should be carefully preserved and applied to the soil; the elements of which the one is deficient being supplied by the other.

In the following table are exhibited the results of four analyses of farm-yard manure which I made some time since:—

	1	2	3	4
Water	73·22	64·12	65·22	69·14
Organic matter	21·17	29·28	28·14	24·21
Phosphate of lime	1·73	1·75	1·88	1·64
Alkaline salts	1·30	1·09	1·86	0·94
Lime and Magnesia ...	1·38	1·82	1·24	2·12
Silica, Oxide of iron, &c. ...	1·20	1·94	1·66	1·95
	100·00	100·00	100·00	100·00
Ammonia, free, in combination with acids, and latent	0·150	0·784	0·550	0·612

No. 1 was composed chiefly of horse and cow dung, the urine having drained away, and most of the soluble matters of the dung having been *washed out by rain*. Nos. 2 and 3 were composed of the dung and *urine* of horses and cows, and having been preserved in a proper manner exhibit a much higher per centage of ammonia. No. 4 was composed of the

mixed excrements of horses, cows, and pigs. In every case, of course, the excreta was largely mixed with vegetable matter derived from the straw with which the cattle were bedded.

The following table shows the value of good farm-yard manure, in so far as nitrogen is concerned, in comparison with a number of substances used as fertilisers. The number opposite each substance represents the number of pounds it would take to produce the same effect as 100 pounds of farm-yard manure:—

ANIMAL MANURES.	lbs.	VEGETABLE MANURES.	lbs.
Farm-yard manure ...	100	Farm-yard manure ...	100
Cow dung	125	Fir sawdust	250
Urine of the cow	91	Barley straw	180
Horse dung	73	Oak sawdust	180
Mixed excrements of the pig	64	Oat straw	150
" " sheep	96	Wheat straw	80 to 170
Urine of horses	16	Buck wheat straw ...	85
Liquid blood	15	Green grass	80
Pigeons' dung	5	Fresh sea weed	80
Dry blood	4	Potato tops	75
Feather	3	Wheat chaff	50
Cow hair	3	Pea straw	45
Horn shaving	3	Rapeseed	8
Dry woollen rags	2½	Coal soot	4 to 10
Peruvian guano	2½		

In considering the foregoing table it should be borne in mind that many of the substances therein referred to are but slightly susceptible of decay, and may, therefore, remain for a considerable period in the ground in a state unsuited for assimilation by plants. Thus, 1 lb. guano may produce a more immediate effect than 7 or 8 times that weight of woollen rags, although the latter substance contains a quantity of ammonia little short of that found in the best guano. This arises from the circumstance of the nitrogen in the guano being chiefly in the form of ammonia, in which condition it enters readily into the

organism of the plant; but in woollen rags the nitrogen exists in an insoluble condition, and it is only by the decay of the rags, which takes place very slowly, that its nitrogen, by being converted into ammonia, is rendered available for the use of the plant.

Exclusive of human excrements, usually added to the compost heap, we may consider farm-yard manure as being composed of the following materials:—Mixed excrements of cows, horses, sheep, and pigs, together with straw; each shall be considered separately.

I.—URINE AND FÆCES OF THE COW.

The dung of cows is termed *cold* because it putrefies very slowly, and, therefore, gives out but little heat. It may here be remarked that the amount of heat evolved by certain kinds of manure when applied to a field is often so considerable as to elevate the temperature of the soil to a very sensible degree. The term *cold*, therefore, applied to a manure which does not rapidly decay is quite correct—decay being, in fact, a species of combustion, slow, to be sure, but, nevertheless, attended, as in the case of more rapid combustion, with the evolution of heat.

Cow dung contains a large proportion of water, and but little phosphoric acid and nitrogen. When partly decomposed it forms a coherent, unctuous mass, which is with difficulty distributed evenly through the soil. Cow dung is the least valuable of the excrementitious matters which make up the manure of the farm yard.

The urine of cows is much richer in nitrogen than their solid excrements, and altogether is far more valuable as a manure than the latter. The urine of calves, and of cows yielding milk, contains much less nitrogen than is found in the urine of bulls or of barren and farrow cows.

1000 pounds of the urine and of the dung of cows contain respectively on the average the following :—

	Dung.	*Urine.*
Solid matter	140	85
Containing Nitrogen	3·5	9
„ Phosphoric acid ...	3	—
„ Alkaline salts	2·20	16

II.—FÆCES AND URINE OF THE HORSE.

Horse dung, weight for weight, is more valuable than cow dung. It contains less water than the latter, is much less coherent, and crumbles readily. It is termed a *hot* manure, as it decomposes very rapidly. The fertilizing effect of horse dung commences almost immediately on its introduction into the soil; and not only does it enter into a state of fermentation spontaneously, but it also induces, by contact, a like state in other manures having a less tendency to decay.

The solid and fluid excrements of the horse contain each in 1000 parts the following :—

	Dung.	*Urine.*
Solid matter	250	100
Containing Nitrogen	6	11
„ Phosphoric acid ...	4	—
„ Alkaline salts	3·5	14

III.—URINE AND FÆCES OF THE SHEEP.

Sheep dung is richer in nitrogen than cow dung, and contains about as much of that element as is found in the solid excrements of the horse. In its tendency to putrefy it may be regarded as intermediate between cow and horse dung.

The urine and dung of well fed sheep contain on the average each in 1000 parts the following :—

	Dung.	*Urine.*
Solid matter	360	50
Containing Nitrogen	6	8
„ Phosphoric acid ...	5	—
„ Alkaline salts	3	9

IV.—URINE AND FÆCES OF THE PIG.

As the food of the pig is of a more varied nature than that of the other domestic animals we may expect to find the composition of its excrements to vary likewise. Pig dung somewhat resembles cow dung, being soft, compact, and *cold*, and not liable to undergo rapid fermentation: when employed alone as a manure it is said to give an unpleasant taste to roots, and even to impart to tobacco a disagreeable flavor. On the continent pig dung is extensively employed as a manure in the cultivation of hemp.

The solid and liquid excrements of the pig contain each in 1000 parts the following:—

	Dung.	*Urine.*
Solid matter	240	24
Containing Nitrogen	7	8
„ Phosphoric acid ...	5	1·2
„ Alkaline salts	6·5	2

V.—QUANTITY OF EXCREMENTS YEARLY PRODUCED BY ANIMALS.

The quantity of urine and solid excrements voided annually by the cow, horse, &c., has been differently stated by different observers. Thus, according to Sprengel, the cow furnishes yearly 13,000 lbs. of urine, whilst Boussingault, from his experiments, estimates the quantity at 6,570. A horse on which Boussingault experimented passed a quantity of urine daily which in a year would have amounted to 1,100 lbs. Vauquelin states that the horse voids annually 1,000 lbs. of urine, whilst, according to Stöckhardt, the quantity is 3,000 lbs. From Doctor Thompson's experiments, we learn that the average daily dung of a cow weighed about 7¾ lbs.; yet other experimenters inform us that that amount is below the average. With such discrepant statements in connection with this subject before us, would it not be desirable for some one to

undertake an extended series of experiments, with the view of determining the mean quantities of urine and dung annually furnished by those animals whose excrements are employed as fertilizers? Such experiments, if accurately conducted, would, in conjunction with analysis, determine exactly the value of these animals to the farmer as producers of manure.

The quantity of urine passed by the horse is certainly but little more than that excreted by man. Indeed, it appears strangely small when contrasted with the large quantity of water which this animal consumes, amounting to several gallons daily. This is accounted for by the great evaporation which takes place from the large surface of the horse's body. The greater portion of the water, instead of being voided as urine, passes off as insensible perspiration, and is thrown out from the lungs during the process of respiration.

VI.—STRAW.

On the continent straw has long been esteemed as a valuable manure, but it would not appear by its chemical composition to possess any remarkable fertilizing properties. It will remain for a considerable period in the soil without producing any sensible effect; but when saturated with urine or mixed with fermenting dung, it will then decay, and its efficacy will be more immediate and powerful. In some countries the straw is burned on the field and its ashes ploughed in. Straw improves the texture of heavy, tenacious soils by opening them, and allowing the free access of air. To light soils, the fault of which is being *too open*, straw should not be applied unless in a state of fermentation. 1000 parts of dry wheat-straw contain about 4 per cent. of nitrogen and 3 per cent. of phosphoric acid: in oat-straw, the amount of these substances is somewhat less.

VII.—MANAGEMENT OF FARM-YARD MANURE.

Farm-yard manure should not be exposed to the influence of the sun, air, and rains, as too frequently it is the case, and in consequence of which its volatile and soluble constituents—the most valuable portion of the manure—are lost, the volatile being dissipated into the atmosphere, and the soluble washed away. The dark coloured liquid which is so frequently observed trickling from the badly preserved manure heap contains in solution its richest fertilizing constituents.

The saving effected by carefully preserving farm-yard manure from loss by exposure and evaporation is clearly shown by KOERTE's experiments. He found that 100 loads of dung preserved in the usual manner were reduced at the end of

	Loads.		*Loads.*
81 days to	73·3	sustaining a loss of	26·7
285 „	64·4	„	35·6
384 „	62·5	„	37·5
499 „	47·2	„	52·8

Thus, at the expiration of a period extending over sixteen months, we find the manure had dwindled to less than one-half its weight. Nor was this alone the loss sustained, for the half which disappeared bore with it nearly all that was valuable in the manure, leaving behind a mass of matter which, regarded as a manure, possessed qualities little superior to so much rotten straw or saw dust.

Instead of allowing the dung to accumulate in the farm-yard, it would, at least in most instances, be unquestionably preferable to have it distributed over the field at once, to be ploughed in or not, according to circumstances. In the case of heavy, cold soils, the manure might, with great advantage, be ploughed in whilst in a fresh state, but, of course, some time previously to the crop being sown. The fresh manure acts mechanically upon heavy soils, rendering them loose and

poros, thus favoring the free access of air. On cold soils it acts beneficially by evolving, during the progress of decay, a considerable amount of heat, and as a consequence rendering the soil warmer. It may be here remarked that a warm habitation is almost indispensable to the young and tender seedling.

In the case of light, sandy soils it is better not to apply the manure until it has been fermented, as soils of this description are sufficiently poros—often too much so, and their temperature is in general sufficiently elevated for the purposes of vegetation.

There is no appreciable loss occasioned by the manure being spread upon the surface of the field, as its fertilizing constituents are absorbed and retained by the soil; the only effect produced by the rain being to carry those matters down into the soil, where they remain safely stored in reserve till the period arrives for their being appropriated by the plants. These remarks, however, apply only to coherent or to moderately loose soils. Spread upon light, sandy soils the manure would sustain a loss, as soils of this character are not capable of retaining, at least in any marked degree, the soluble matters of the manure.

VIII.—CONSTRUCTION OF LIQUID MANURE TANKS.

Cisterns for the reception and preservation of drainings, or liquid manure, have long been in use in many countries, particularly in those more devoted to tillage than pasturage.

Liquid manure tanks are now regarded in the light of necessary adjuncts to the farmstead, and justly so, for, owing to a variety of reasons, the strictest economy in every department of farm management must be observed, in order to render husbandry a profitable pursuit. Bearing this in mind, a few hints on the construction of these manurial repositories,

without entering into elaborate details, may not be irrelevant in a work such as this, and more especially as failures have, in numberless instances, been the consequence of not devoting some forethought and consideration to this subject. Those failures have arisen chiefly from a desire on the part of the designers of the tanks to insure the utmost economy in their construction, by which the greatest cubical capacity might be obtained at the least possible expense; hence the adoption of the cubical form, without due consideration of other very important points. The omission of considering the nature of the ground where it is desirable or necessary to construct the tank, has frequently led to great disappointments and increased expense in repairs and reconstruction, which, by a little care and additional outlay at the outset, would have been spared: for instance, when the depth of the tank is considerable, and the ground in which it is sunk is very humid, it is found that, owing to the pressure of the contents of the tank from within, and of the water from without, it is scarcely possible to render the tank water tight. In such cases attempts have been made to prevent the liquid from oozing through by lining the tank with cement. While the tank is full the pressure of its contents is sufficient to balance that caused by the water from without; but when it is empty the external water, having no counterpoise, will soon throw off the lining, and even if this should resist, it will force its way up through the bottom and fill the tank to the level of the circumambient water. Therefore, the difficulties, and, in the end, the expense of constructing a tank will diminish in proportion as the depth decreases. It is in consequence advisable to limit the depth of the tank to six or seven feet, or even less, when the land is unfavorably circumstanced as regards drainage: and to save expense in arching, the width should not exceed from six to eight feet. Therefore the capacity must be increased to the

desired extent by extending the length; but where, of necessity, the length is limited, the requisite capacity can be readily and economically obtained by building two or more tanks side by side, which may be arched or vaulted over from the side to the dividing walls.

When the underlying rock consists of impertransible clay, free of springs, the expense will not be great in flagging the bottoms of the tanks, and building side walls and arches; but when, on the contrary, the excavations necessary for the construction of tanks are made in ground of a wet and pervious character, or subject to springs, then the following precautions should be adopted in order to prevent the contents of the tanks from leaking, or the external water from forcing an entrance. In the case of springs the remedy is obvious, simply to intercept and discharge them into the nearest drain or outlet. In the other case, the tanks ought to be puddled with good cohesive clay, behind and under the stone and brick work. This should be done in the following manner:— A layer of clay, well tempered with sufficient moisture to render it slightly cohesive, should be spread over the bottom of the excavation, and well beaten and rammed down about a foot in depth, and a foot every way beyond the intended foundation of the walls. When this is done, the bottom, including the space necessary for the foundation of the walls, should be paved with flags well jointed, or with bricks set edgeways. As the walls are being carried up, puddle, at least a foot in thickness, should be well rammed in between them and the tanks.

The arches of the tanks may be built either of rubble masonry or of bricks. A man-hole should be made at each end to permit access to the interior, as occasion may require. There should also be an opening for the pump. The tanks are best placed so that when full they will be under the level

of the discharging pipe. The best conduits from the several sources of the drainings to the tanks are made of glazed earthen pipe tiles, jointed with cement, so as to be air tight. They should be furnished at the receiving ends with grates, to prevent their being choked by the passing down of solid matter.

As liquid manure is usually preserved for a month or two, and sometimes longer, either to allow it to ripen, or until it is required for use, it is necessary to construct a number of tanks, or partition a large one into compartments. Thus there will always be a tank of drainings ready for use, another filling, and the rest undergoing the process of fermentation. In a system of tanks each should be furnished with a sluice to shut off the supply when full, and direct the stream to the next in order of filling.

IX.—TREATMENT OF LIQUID MANURE.

Liquid manure, on being kept for some time, becomes considerably altered in its chemical composition. It acquires a pungent and disagreeable odor, the same which we recognize when the door of a well-closed stable is first opened in the morning. This odor is attributable principally to the presence of ammonia, which is always produced during the putrefaction or fermentation of substances containing nitrogen. If this ammonia be allowed to escape from the liquid manure, as too frequently happens, a loss is occasioned greater than if one-half the original quantity of manure had been wasted.

By judicious management all the nitrogen existing in liquid manure might be preserved. Chemistry has pointed out many substances, by the addition of which to the liquid manure, this most desirable result would be unfailingly accomplished. I shall briefly notice a few of the more important of these substances.

The carbonic acid and ammonia, simultaneously produced by the fermentation and putrefaction of urine or drainings, enter into combination. Both substances are naturally gaseous, and the body resulting from their union—*carbonate of ammonia*, although not a gas, is yet so volatile in its nature, that on exposure to the air it gradually passes away from the liquid which held it in solution. The mode of preserving the ammonia or its compounds from being thus lost by evaporation is simple enough; we have but to add to the drainings a sufficient quantity of sulphuric acid. This causes the ammonia to separate from the carbonic acid, and produces with it a substance—the *sulphate of ammonia*—which has no tendency to evaporate, and which will remain unchanged for any period during which the drainings may be reserved. 100 lbs. of sulphuric acid of commerce will be sufficient to "fix" about 34 lbs. of ammonia. The cost of the acid would, at 1d. per lb., be 8s. 4d. The value of the 34 lbs. of ammonia with which it would combine, would, at the lowest price of manurial substances, be 17s., or more than double the cost of the acid. Sulphuric acid does not in the slightest degree impede the fertilizing action of ammonia; on the contrary, there is abundant evidence to lead us to believe that it promotes it. It is generally considered that sulphuric acid causes a luxuriant development of the leaves of clover and other esculent vegetables, and increases in a very sensible degree their power of absorbing ammonia from the atmosphere.

About three or four pounds of sulphuric acid would be required to fix *all* the ammonia which the complete putrefaction of 100 lbs. of drainings would produce, but 1 lb. of the acid would be sufficient to prevent 150, or even 200 lbs. of drainings from losing any appreciable quantity of ammonia.

Two substances containing sulphuric acid—viz., *gypsum*

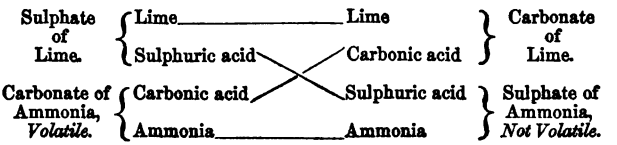
and *green vitriol* may be substituted for oil of vitriol, as "fixers" of ammonia.

For the preservation of liquid manure, green vitriol (copperas or sulphate of iron) has long been used in Switzerland, where the application of this *vitriolized* manure to meadow lands has ever been attended with the most successful results. 100 parts of crystalized sulphate of iron contain 37 per cent. of oil of vitriol; so that three parts of green vitriol would fix as much ammonia as one part of sulphuric acid.

Gypsum is, perhaps, the cheapest and best substance which the Irish farmer could employ to preserve the strength of his liquid manure. It may be purchased at one-sixth the cost of oil of vitriol, and it is much cheaper than copperas, besides containing more sulphuric acid than is found in that substance. 100 parts of anhydrous or native gypsum contain 59 per cent. of dry sulphuric acid, equivalent to 72 per cent. of oil of vitriol. 100 parts of hydrated sulphate of lime (plaster of Paris) contain, of dry sulphuric acid, a quantity equivalent to 57 parts of oil of vitriol.

Gypsum should be added to drainings in a pasty state; and as it is but very sparingly soluble in water—to the extent of a grain to the ounce of water—and has a tendency to settle down to the bottom of the tank, it should occasionally be stirred up and well mixed with the drainings, otherwise its action would be very slow.

The changes which take place when gypsum and carbonate of ammonia, in solution, are brought together, are rendered intelligible by the following diagram:—



The carbonate of lime (chalk) produced by this decomposition is by no means a useless addition to the manure. Being in a very minute state of division—a condition favorable to its being dissolved by the carbonic acid of the soil—it acts beneficially, in the event of the soil not containing a sufficient quantity of lime in a digestible form to meet the requirements of healthy vegetation.

I have, perhaps, entered too minutely into the chemical composition of gypsum, but the term "hydrated sulphate of lime" appears so frequently in the analyses of superphosphate of lime and other artificial manures, that it is well the farmer should be acquainted with the nature of this substance.

Salts of magnesia have been employed as fixers of ammonia, and, as such, have been recommended by many agricultural chemists, more especially by Boussingault. Magnesia acts by combining, not only with the ammonia of the drainings, but also with its phosphoric acid—all three being precipitated as an insoluble compound, named by chemists, the *ammoniaco-phosphate of magnesia.* About 12 lbs. of sulphate of magnesia (Epsom salts) would be sufficient to save all the ammonia and phosphoric acid usually found in 100 gallons of liquid manure.

As the ammoniaco-phosphate of magnesia is a *very* insoluble substance, it does not appear to me that its employment as manure could be attended with very advantageous results. Indeed, the experiments of Polstorff, a German chemist, which appear to have been very carefully conducted, show that this substance had no influence whatever on the development of the grain of barley, whilst it acted prejudicially upon the formation of its straw. Similar carefully conducted experiments would, in all probability, show that its application, in the case of wheat or other cereal crops, would be attended with a like result.

Quick-lime is sometimes employed to preserve the manurial virtues of drainings. Its application should, however, be guided by a knowledge of the condition of the manure. If it be *ripe*, *i.e.*, fermented, it will contain ammonia in combination with acids; the quick-lime will combine with these acids, and the ammonia being thus liberated will assume its natural gaseous or aëriform state, and fly off into the atmosphere. Thus *the application of quick-lime to putrid drainings is attended with great loss.* On fresh drainings, in which no ammonia exists, quick-lime exercises a preservative effect. It causes the nitrogen of the manure to combine with oxygen and form the valuable manurial substance, *nitric acid.* The nitric acid thus produced enters into combination with the lime, and by this means a salt, the *nitrate of lime*, is formed, which *is not volatile*, and which, as a source of nitrogen, is considered to be fully as valuable as the salts of ammonia.

I have, at the present moment, in an open vessel, a quantity of urine which was mixed with a little quick-lime nearly six months since, and although constantly exposed to the action of the air, it has not acquired a disagreeable odor, nor has it lost any of its fertilizing constituents.

The property of absorbing gases which charcoal possesses in a remarkable degree, renders it an excellent adjunct to those manures which contain free ammonia, as it is capable of absorbing into its pores nearly 100 times its volume of this gas, which it gives off gradually to the plants when placed in the soil. The use of this substance applies, however, rather to the solid than to the liquid manure of the farm-yard. There is one mode, however, in which its use is recommended in the saving of drainings—namely, mixing the charcoal as a coarse powder with a little gypsum, and spreading the mixture under the litter of the stock. The urine will be absorbed into the pores of the charcoal, and be there safely stored, and what-

ever ammonia is formed will be fixed by the gypsum. Peat charcoal, turf mould, or any other substance of a similar nature may be substituted for the charcoal.

When the farmer is disinclined to add any preservative substance to his liquid manure, he should, at least, dilute it with two or three times its weight of water; by this means much of the ammonia will be saved, and the fermentation of the manure will not proceed so rapidly. This will render necessary the construction of larger tanks than usual, but the increased expense will be more than compensated by the great saving effected in the manure. It should also be borne in mind that the undiluted drainings not unfrequently burn up grass when applied to it in dry weather, and also exercise an injurious influence on growing crops generally.

X.—ON NIGHT SOIL AND URINE.

The fæces or solid excrement of man yields, by drying, about 25 per cent. of solid matter, which consists of undigested food, woody fibre, fatty, waxy, and resinous bodies, silica and other insoluble constituents of the food, and traces of soluble salts.

The value of human excrements as manure depends, to a great extent, upon the quantity and quality of the food used by the individual. In the fæces of the wealthy, who in general consume animal food in greater quantity than is necessary to restore the *waste* of their systems and maintain the process of respiration, the amount of nitrogen and other fertilizing substances must be much more considerable than the quantity occurring in the excrements of persons who are poorly fed, and whose diet is principally vegetable. Indeed, there can be but little doubt that the night soil from a club

house or fashionable hotel would produce, weight for weight, a far greater fertilizing effect than that obtained from a workhouse.

We may assume 1000 lbs. of recent night soil to contain on the average the following:—

		Value in money.
		s. d.
Water	750	
Organic matter	225	
Containing Nitrogen	(8)	5 4
Inorganic matter	25	
Containing Phosphoric acid (insoluble)	(8)	1 0
		6 4

The following analysis by WAY more fully exhibits the composition of night soil. The first column shows the composition of the ash; the second, that of the dried excrement.

ANALYSIS OF DRIED HUMAN FÆCES.

	Composition of the ash.	Composition of the dried excrement.
Organic matter	—	88·52
Insoluble silicious matter ...	12·79	1·48
Oxide of iron	4·66	0·54
Lime	14·98	1·72
Magnesia	13·48	1·55
Phosphoric acid	37·17	4·27
Sulphuric acid	2·10	0·24
Potash	10·40	1·19
Soda	2·83	0·31
Chloride of sodium	1·59	0·18
	100·00	100·00

Human urine is subject to considerable variation in composition; some specimens having been found to yield but 3½ per cent. of solid residue, whilst others have afforded nearly double that amount.

The urine of persons who use an animal or mixed diet, or whose food contains more nitrogen than is required for the

reparation and supply of tissue, contains a much greater quantity of urea* than is found in the urine of those who consume, in just sufficient quantity, a mixed or vegetable diet. M. Lehman, who has studied this subject, informs us that he obtained from his urine of twenty-four hours :—

	Grains of Urea.
After a non-nitrogenous diet ...	237·909
After a vegetable diet	347.061
After an animal diet	821·270
After a mixed diet	501·704

Although we have not sufficient data to enable us to state, with any degree of accuracy, the average composition of the urine of the population of these countries, yet, from the results of numerous analyses of this fluid, performed by others, as well as by myself, I consider the following figures as being at least approximatively correct :—

1000 lbs. of urine contain—

			Value in money.	
				s. d.
Water		955		
Solid matter		45		
Containing	Nitrogen	10	6	8
,,	Phosphoric acid (soluble)	1½	0	7½
,,	Salts of Potash ...	3	0	4½
,,	Salts of Soda ...	8	0	1
			7	9

The quantity of urine passed in the year by an adult is estimated at about 1000 lbs., the value of which, at the present rate of artificial manures, would be the above sum.

This bears upon the assertion of Mr. Smith of Deanston, who states that the urine of two men is sufficient manure for an acre of land. We may, however, safely assume, that the

* Next to water, urea is the most abundant constituent of urine. As it contains 47 per cent. of nitrogen, and decomposes spontaneously, producing ammonia, we can easily understand that the more of this substance contained in the urine the more valuable is it as a manure.

mixed excrements of four men are sufficient to maintain the fertility of an acre of tillage land.

The value of urine and night soil as fertilizers has long been known and appreciated in Flanders, where agriculture is certainly carried on in a more enlightened manner than with us. In that country no urine is allowed to ferment in open pools, to send poisonous exhalations into the atmosphere, or permitted to run into rivers to pollute their waters. To the Flemish agriculturist the urine tank, which is carefully and substantially built and covered over, is as much a matter of consideration as the stable or any other adjunct of the farmstead. Not only do the Flemish farmers use up the night soil and urine produced on their own farms, but they enter into arrangements with persons to supply them with the contents of the cesspools in the towns. The mixed excrements of an individual are valued at nearly £2 per annum. The farmers cart the manure from the towns, and store it up in underground receptacles set in the corners of their fields. When required, it is pumped up and applied scrupulously by measure—so many gallons to so many square feet of land. All this labour and certain outlay are undertaken by a people whose limited means admit of no doubtful experiments or slow return of profits. To a people of such limited capital and small holdings, the failure of an experiment of any magnitude in agriculture, or a delay in the realization of a profitable return, would be ruinous. In all their operations they must be governed by a well-grounded conviction of an immediate profit. Of this they have every reasonable certainty from their experience and from the immemorial practice of their country.

Belgium thus supplies us with the best possible evidence that the value of night soil and urine is so great as to justify the most cautious community or individual in incurring con-

siderable expense in order to prevent the night soil and urine of towns from being wasted.

In Paris and many other continental cities the night soil is dried, mixed with various substances, such as gypsum, charcoal, &c., and sold under the name of *poudrette*. The preparation of this manure is not, however, in general, conducted in the most scientific manner. It seldom contains even 2 per cent. of nitrogen, the greater portion of this element escaping during the drying of the manure, and being otherwise wasted. The attention of manufacturers being directed to this loss, various improvements have been, and are being, made, and no doubt, before long, by the adoption of an improved process, poudrette will be a really powerful fertilizer.

In no country on the face of the globe is there exhibited so high an appreciation of the fertilizing properties of night soil as in China. Throughout the entire of this extensive empire, every city and town has arrangements for the reception and preservation of this manure. In every habitation there is a vessel reserved for the manurial contributions of its inmates—the effluvia arising from which is regarded by the Chinese of all ranks, from the mandarin down to the peasant, with the most perfect indifference. This, of course, can easily be accounted for, from their being habituated to it from infancy, and is readily tolerated, because of the immense return which the manure yields in the field.

In China, weeds are rarely observed in the corn fields, as the dung of animals, which contains seeds, which have passed through their bodies unchanged, is seldom used as a manure: the excrements of man being almost the only kind employed.

In the Celestial empire thousands of persons earn their livelihood by collecting night soil, mixing it with clay, and then drying the compound. This they name *taffo*, and sell it

in the public markets of the cities, just as any other commodity.

A modern writer, who had the opportunity of personally observing it, thus describes the means adopted by the Chinese for the securing of this manurial substance.*

"Almost every Chinese town is placed on the banks of a river or canal, and the water is generally led, not only round the walls, thus forming a kind of moat, but also through many parts of the city. Long, clumsy boats are placed in different departments of the town into which the urine and night soil are emptied, and conveyed from thence into the country. The fields in the neighbourhood of cities are generally supplied with it by coolies, who go every morning to market loaded with the produce of their farms. Each brings home two buckets of this manure slung at the ends of his bamboo pole. In England it is generally supposed that the Chinese carry the night soil and urine to these tanks, and leave it there to undergo fermentation before they apply it to the land. This, however, is not the case, at least not generally. In the fertile agricultural districts in the North I have observed that the greater part of this stimulant is used in a fresh state, being, of course, sufficiently diluted with water before it is applied to the crops, and there can be little doubt that in this the Chinese are perfectly right, as the manure must be much more efficient in this state than when a great portion of its ammonia has passed off into the air."

The value of human fæces and urine as powerful fertilizing stimulants being thus established by the experience of the Chinese, and for many years amply recognized on the continent of Europe, it seems surprising that it has not been more eagerly sought after in these countries. There are, no

* Fortune's Wanderings in China.

doubt, antipathies to be overcome. Prejudices, it is true, exist against the introduction of human excrements as manure. The preservation of public health and decency, and other considerations, are regarded as being involved in the question; but whenever the project is seriously undertaken, and sufficient capital invested in it, there will not be wanting mechanical or scientific skill to overcome whatever difficulties may be in the path, and all the objections referred to, so completely removed as to satisfy the most fastidious.

X.—ON BONES.

The discovery of the fertilizing properties of bones formed the dawn of a new and important era in farming. Already it may be said to have effected a complete revolution in the art of agriculture. That event taught those engaged in the cultivation of the soil to depend less than they had been in the habit of doing, on that panacea for *sick* soils—farm-yard manure. It paved the way for the introduction of a class of fertilizers—"Artificial manures"—the use of which has restored the strength of exhausted lands, exalted the fertility of naturally good soils, and in many districts where local peculiarities prevented the introduction of bulky manures, it has facilitated the adoption of improved modes of cultivation, and added accordingly to the profits of the cultivator of the soil.

Bones consist of two portions, the one organic and combustible, the other earthy and incombustible. The organic part is composed of a very nitrogenous substance, termed *cartilage*, which, by boiling or steaming, is converted into *gelatine*. The earthy matter consists, for the most part, of

the valuable manurial substance, *phosphate of lime.* The following analysis by the great Swedish chemist Berzelius, exhibits the composition of the bones of the ox when dried and freed from fat and membrane.

100 parts of the bones contain:—

Organic matter	33·30
Basic phosphate of lime with a small quantity of fluoride of calcium	57·35
Phosphate of magnesia	2·05
Carbonate of lime	3·85
Soda, with a little chloride of sodium	3·45
	100·00

It will be observed that in the analysis the magnesia is shown in the state of carbonate; the probability, however, is, that this is the result of the process of calcination, and that in the bone it exists under the form of phosphate.

The amount of phosphoric acid in bones varies with the age and species of the animal. Bones thus differ materially as to their value in agriculture. The bones of fishes contain, in general, less earthy, and more organic matter, than is found in the bones of the mammalia.

The analysis of the cranium of a cod fish gave in 100 parts the following:—

Organic matter	43·94
Phosphate of lime	47·96
Carbonate of lime	5·50
Phosphate of magnesia	2·00
Soda, with chloride of sodium	0·60
	100·00

The phosphate of lime found in bones is regarded by chemists as a peculiar combination of phosphoric acid with a base. It consists of eight chemical equivalents of lime

united with three chemical equivalents of phosphoric acid. Centesimally its composition is—

51·12 of lime and
48·88 of phosphoric acid.

The organic portion of the bones of oxen yields by decay, about 5½ per cent. of ammonia, and a considerable quantity of carbonic acid. Nevertheless, many samples of bones sold for the purpose of being employed as manure have been found to yield but a very small quantity of ammonia, arising either from their being exposed for a long time to the influence of the air, &c., or to their having been sophisticated by fraudulent dealers. The following table exhibits the results of six analyses which I have made of bones derived from various sources :—

	1	2	3	4	5	6
	Beef Bones from a Dublin Butcher.	Bones from a Bone-yard.	Bones from South America.	Bone-dust from England. (adulterated.)	Bone-dust from England.	Bone black from a German sugar refinery.
Organic Matter ...	34·60	30·18	28·30	33·12	33·12	24·15
Containing Nitrogen	6·04	4·58	3·98	4·90	4·90	2·37
Earthy Phosphates ...	54·22	55·60	56·15	55·22	55·22	65·31
Alkaline Salts	3·75	3·14	1·40	3·10	3·10	3·62
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Calculated value per ton,..	7 6 11	6 12 2½	6 3 0½	4 0 9	6 19 6	6 1 3½

The fertilizing properties of bones depend almost entirely upon their nitrogen and phosphoric acid. Containing but a small proportion of alkalis, they ought to be regarded as a special or subsidiary manure, although I have enumerated them under the head of general manures. Their effects,

therefore, in soils deficient in soluble potash and soda, may be materially promoted by the admixture of common salt, the cheap salts of potash, such as the crude sulphate, &c.

The rapid effects of bones depend altogether upon the state of division to which they are reduced. When simply broken into small pieces, their action, though not energetic, is extended over a long space of time; but when finely pulverized, or subjected to the action of high pressure steam, their influence is immediately exerted, as the decay of the organic matter takes place with greater rapidity, producing ammonia; and the structure of the bone being thereby broken up, the phosphate is readily acted upon and dissolved by the carbonated water* and other solvents present in the soil.

"DISSOLVED" BONES.

Various plans have been proposed for rendering the effects of bones more immediate: instead of their fertilizing action being extended over a lengthened period, it has been proposed to expend it, if possible, even during the first year of their application. The mode most generally adopted for accomplishing this object, is that of acting upon the bones by means of sulphuric acid, which so alters the insoluble phosphate of lime, that it is easily dissolved in the moisture of the soil, and presented to the plants in a condition favorable to its being taken up by them.† Bones acted upon by sulphuric acid are known in commerce under the names of *vitriolized bones*,

* Dumas was the first to prove that phosphate of lime, though insoluble in pure water, is dissolved in appreciable quantity, by water charged with carbonic acid.

† Liebig, in his celebrated and truly enlightened work on Agricultural Chemistry, published in 1840, was the first to make generally known the properties of vitriolized bones as a fertilizing agent; but, as I am informed, long before that period, my friend, Sir James Murray employed this substance in agriculture with the best results. The following

sulphated bones, dissolved bones, superphosphate of lime, &c. The first of these terms appears preferable.

Every manufacturer of vitriolized bones adopts a mode of manipulation of his own; and numberless recipes are given for the preparation of this article. Of one thing, however, we may be certain, that unless the bones are finely pulverized, or else treated with high pressure steam until they become so soft as to be easily reduced to a pulp, a large proportion of their phosphate of lime will be unacted upon by the acid, and

letter which I received from Sir James, whilst these sheets were passing through the press, will, I trust, be the means of establishing his claim as the *first* discoverer of the manurial value of this substance:—

Dublin, Temple House, 8th June, 1857.

MY DEAR DR. CAMERON,

It is truly encouraging to see yourself and other eminent chemists engaged in lecturing upon, and investigating into, the important science of agriculture. Forty years ago I ventured to do the same, but I was considered a visionary because I had the courage to proclaim that soils, like animals, suffered from particular diseases, and required particular remedies.

Many years since, I was connected with extensive chemical works, where large quantities of phosphate of soda were prepared. Chemists well know that to make this salt it is necessary, first, to act upon bones by means of sulphuric acid, by which a soluble or biphosphate of lime is produced. I had the curiosity to try what effect this biphosphate of lime, or dissolved bones, would have upon the crops which were being raised in the neighbourhood of the works, and the results were such as to astonish every one who witnessed them.

This was about the year 1817, and various accounts of my experiments appeared in the public journals.

In 1834–5 I lectured in Dublin upon the value of soluble phosphate of lime and other chemical substances as fertilizers, and subsequently wrote a small book on the same subject, entitled "Advice to Farmers," which was published by Longman and Co., London. On the 17th May, 1841, my son, John F. Murray, of Lincoln's Inn, lodged a caveat for the application of the soluble phosphate of lime as a fertilizer. The first caveat ever lodged for such a purpose.

In the work which I enclose you,* and to which I beg your atten-

* Trials and Effects of Chemical Fertilizers, with various experiments in Agriculture. By Sir James Murray, M.D. Dublin, Curry & Co. London, Longman & Co. 1843.

will consequently remain in an insoluble condition; whilst the unused acid remains free to act corrosively on the plants with which it comes in contact.

The following excellent process for preparing vitriolized bones is adopted at the Messrs. Perry's works, in the county of Antrim:—

The bones, after being reduced to powder in a powerful mill, are introduced into a *Papin's digester*, into which steam is admitted at a pressure of 20 lbs. to the square inch. In the course of two hours the bones become so soft as to allow of their being easily beaten into a pulp. In this condition they are placed in a pan with about half their weight of oil of vitriol, which rapidly renders the phosphate of lime soluble. The freshly prepared compound is next mixed with a portion

tion, you will find extracts which I consider fully substantiate my claim as being the first to employ the soluble bone earth as a manure. This will be evident from the following extract selected from the printed syllabus of a course of lectures which I delivered in 1835, at the Royal Exchange, Dublin:—

"HEADS OF LECTURES.

"1st. Furnishing *soluble superphosphate of lime*, in combination with other chemicals, instead of the *insoluble phosphate* hitherto in use."

The following is an extract from one of the lectures:—

"For districts where bones are scarce, the native bone-earth (which I now send round for your inspection) affords an excellent substitute. This mineral or rock contains phosphoric acid, in combination with lime; common strong acids take the lime, and set free the phosphoric acid, which is then ready to unite with any alkaline material, such as soda, potash, or ammonia."

I know you will excuse my troubling you with this long statement, for you are always anxious to see justice done to discoverers. People may object to my entering into this matter, and cry "*cui bono*," "what use is it now to enquire into the history of the discovery of the fertilizing qualities of vitriolized bones;" but you are aware that the true history of such early struggles always acts as an incentive to young investigators.

Believe me, my dear Doctor,
Ever truly yours,
JAMES MURRAY.

Doctor Cameron.

which had been previously made and dried, so as to cause it to assume a certain degree of consistence; the whole is then transferred to a hot air chamber, where it is dried at a moderate heat. I have analyzed the bone compound prepared in this manner, and find the results to be highly satisfactory.

The following mode of preparing vitriolized bones has been lately recommended on account of the saving of acid which it effects; also, because it can be readily followed by those farmers who desire to prepare the article for themselves:—

Ordinary bone dust is sifted and the coarsest pieces treated with sulphuric acid.* When these have had time to get well soaked, about half its weight of water may be added to the acid, accompanied by constant stirring. By the combination of the water and acid great heat is evolved, which is highly favorable to the operation, facilitating very much the action of the acid on the bones. The coarsest particles of the remaining portion are next added, and the fine dust kneaded in, two or three days after.

It is said that 100 lbs. of bone dust, treated, in this manner, with 25 lbs. of sulphuric acid and 13 lbs. of water, yield about 130 lbs. of superphosphate of lime, which is capable of exerting the same fertilizing effects as 200 lbs. of the ordinary superphosphate.

The chemical changes which take place when bones are acted upon by sulphuric acid are as follow:—

1. The carbonate of lime is converted into sulphate of lime.

* In places where muriatic acid may be obtained at a cheaper rate than oil of vitriol, the former may be substituted for the latter in the preparation of superphosphate of lime. For this purpose 2½ lbs. of muriatic acid are equivalent to 1 lb. of sulphuric acid. When muriatic acid is employed, the bones are really "*dissolved*," as that acid forms with lime not only a soluble, but a highly deliquescent compound—*the muriate of lime (chloride of calcium)*.—AUTHOR.

This accounts for the violent effervescence, or escape of carbonic acid gas observed during the process.

2. The basic or insoluble phosphate of lime loses a portion of its lime, which is appropriated by the sulphuric acid, forming with it the sulphate of lime. It is thus that so large an amount of gypsum is found in vitriolized bones.

3. The lime remaining unappropriated by the sulphuric acid forms, with the excess of phosphoric acid, a compound which is readily soluble in water.

The insoluble or bone phosphate of lime is decomposed wholly or partially, according to the quantity of acid employed. One equivalent, or 438 parts, of bone phosphate, with eight equivalents, or 392 parts, of sulphuric acid, will produce sulphate of lime and phosphoric acid. 438 parts of bone phosphate, with 245 parts of sulphuric acid, yield sulphate of lime and *biphosphate of lime.* This last consists of one equivalent of phosphoric acid and one of lime. It is an acid substance, very soluble in water, and, therefore, readily available for the use of the plants into whose organism it is intended to enter. This, however, probably seldom takes place, as when biphosphate of lime is mixed with earth, the carbonate of lime, which is always present in every fertile soil, takes from it half its phosphoric acid, the whole being converted into neutral or insoluble (in pure water) phosphate, the carbonic acid which was in combination with the lime escaping at the same time. The insoluble phosphate of lime thus produced, or rather reproduced, is, however, in a very different condition from that in which it was before undergoing these chemical processes. It is in a state of extremely minute division, in which it can be easily taken up by the solvents in the soil.

Vitriolized bones are generally esteemed the most economical and effective of bone manures. Their use in promoting

the growth of young turnips so rapidly as to save them from the ravages of the fly, is regarded as a striking example of their very great utility. But from what has been said it must be evident that these effects are not mainly due to the fertilizing properties of the sulphuric acid employed in their preparation, and that their superiority over ordinary bones arises simply from the gelatinous and easily soluble condition produced by the action of the sulphuric acid. A question then arises as to whether a cheaper method of rendering them soluble could not be devised. I do not wish it to be understood that I, for a moment, question the excellence of vitriolized bones. On the contrary, I consider that agriculturists owe a debt of gratitude to those experimentalists who first proposed the employment of that excellent manure. But when we are acquainted with the *rationale* of its action, and know for instance that a given weight of bones contains fully 40 per cent. more phosphoric acid than the same quantity of the *more costly* vitriolized bones, and that in guano, the fertilizing effects of which are unquestionable, almost the whole of the phosphate of lime is in an insoluble condition, it is evident that a less costly mode of rendering the effects of bones immediate is desirable.

If some of our practical farmers would undertake a series of experiments, extending over a period of three or four years, I think they would find that, weight for weight, thoroughly ground and steamed, or even fermented bones, would be much cheaper than the commercial superphosphate of lime. As a contribution towards determining this point I here give the results of some experiments bearing directly on the question, which I commenced more than three years ago. It is almost unnecessary to remark that these experiments must be repeated and varied before we can safely deduce any positive conclusion from them.

The plants experimented upon were Skirving's yellow turnip,

The soil was a light loam, of medium fertility, well drained, and containing but little organic matter. The experiments were conducted at Drumcondra, near Dublin.

EXPERIMENTS IN GROWING TURNIPS.

FIRST YEAR.

Manure employed.	Quantity applied per Acre.	Cost of Manure per acre.	Produce per Acre.
	cwt.	£ s. d.	tons cwt. qr.
1—Guano	6	3 0 0	19 19 3
2—Superphosphate of Lime	7½	3 0 0	20 14 1
3—Ground Bones ...	7½	3 0 0	19 18 2

SECOND YEAR.

4—Guano	6	3 0 0	20 13 3
5—Superphosphate of Lime	7½	3 0 0	20 12 2
6—Ground Bones ...	7½	3 0 0	20 15 2

THIRD YEAR.

7—Guano	3	1 12 6	18 3 0
Gypsum	2½		
8—Superphosphate of Lime	3½	1 12 6	12 0 3
Gypsum	3½		
9—Ground Bones	3½	1 12 6	15 18 3
Gypsum	3½		

SUMMARY.

Guano	12½	7 12 6	53 16 2
Superphosphate of Lime ...	18¾	7 12 6	53 7 1
Ground Bones	18¾	7 12 6	56 12 3

The ground bones, guano, and superphosphate of lime were analyzed, and gave the following results:—

	Ichaboe Guano.	Superphosphate.	Ground Bones.
Water	18·47	10·55	6·14
Organic matter, Ammoniacal Salts ...	29·73	22·12	34·25
Soluble Phosphate of Lime	——	16·22	——
Basic Phosphate of Lime, Phosphate of Magnesia ...	34·51	11·33	48·47
Sulphate of Lime ...	——	36·14	——
Carbonate of Lime ...	——	——	6·22
Alkaline Salts	5·44	2·65	3·62
Insoluble matter ...	11·85	0·99	1·30
	100·00	100·00	100·00
Ammonia, combined and latent	8·28	3·28	5·55

The guano and superphosphate of lime were of excellent quality, the latter having been prepared specially for the purpose of being employed in these experiments. The bones were reduced to a fine powder capable of passing through a sieve containing 40 apertures in the square inch. The expense of this process was 2s. per cwt. If the bone dust had been steamed, its effects, no doubt, would have been much more evident.

A mode of *dissolving* bones which is now becoming somewhat general is to mix them with about one-third their weight of clay, saturate the mass with urine, and, having covered the whole with two or three inches of damp clay, allow it to remain for a week or so, when the bones will be found completely disintegrated.* Many intelligent farmers have assured me that bones prepared in this way have proved as efficacious as the best superphosphate of lime. Mr. Campbell, manager of Sir Charles H. Coote's estate in the Queen's County, one of the most enlightened agriculturists in Ireland, informs me that he has tested, in the most complete manner, the comparative effects of vitriolized and fermented bones, and that as he has proved the latter to be fully as effectual as the former, and far cheaper, he has, in consequence, altogether abandoned the use of superphosphate of lime.

The following experiments in connection with this subject will be read with interest by those who desire to economize as much as possible the cost of their manures :—

* During this process great heat will be evolved in consequence of the fermentation of the bones, so that much of the ammonia formed may be driven off. As a remedy for this, I would suggest that to every ton of bones subjected to this process there be added 8 cwt. of gypsum, by which means all the ammonia formed will be converted into sulphate of ammonia, which, as has elsewhere been remarked, is not a volatile substance.

EXPERIMENTS IN GROWING TURNIPS WITH FERMENTED BONES, BY THE LATE MR. PUSEY, PRES. ROYAL AGR. SOC. OF ENGLAND.

First.

Bushels of manure per acre.	Cost of manure per acre. £ s. d.	Produce per acre. tons. cwts.
1—17 bones	... 2 6 9	13 5
2—4½ sulphated bones ...	... 1 2 9	14 5
3—8½ heated bones and sand	... 1 0 9	13 5

The amount of produce was nearly equal, and both preparations show a large saving as against unprepared bones.

Second.

Bushels of manure per acre.	Cost of manure per acre. £ s. d.	Produce per acre. tons. cwts.
1—25½ bones ...	... 3 10 0	14 5
2—7½ sulphated bones	... 2 3 0	14 5
3—12½ heated bones and sand	... 1 11 0	17 1

Mr. Pusey says—"The result of the whole seems to recommend decidedly the mode of preparing bones which I propose,* and, but for the mistake of my men in mixing so small a proportion of sand, I believe the effect would have been much stronger. Practically I think that the manuring virtue of bones is increased from three to four fold by this simple process, which cannot be said to cost anything."

EXPERIMENTS IN GROWING TURNIPS, BY MR. W. M. GLASCOTT, OF ALDERTON, PRIESTHAGGARD, COUNTY OF WEXFORD.

No. 1—One Irish acre, with 8 cwt. of superphosphate of lime, cost £3 4 0
A remunerating crop—about 25 tons.

No. 2—One Irish acre, with twelve bushels of fermented bones, cost 1 16 0
A good crop, nearly equal to No. 1—about 23 tons.

* Mr. Pusey has fallen into an error in supposing that he was the first to propose fermentation as a method of quickening the action of bone manure. It was known and, to some extent, practised years ago.

No. 3—One Irish acre with 2 cwt. of British economical manure,* cost £1 10 0
A complete failure—should have expected a better crop without any manure.

No. 4—One Irish acre, with 12 bushels of fermented bones, and 1 cwt. best guano, cost 2 10 0
An excellent crop—fully 35 tons to the acre.

No. 5—One Irish acre, with 8 cwt. superphosphate, and 1 cwt. guano, cost 3 18 0
An excellent crop—equal to No. 4.

No. 6—One Irish acre, with 5 cwt. best guano, cost ... 3 10 0
A good crop, but not equal to No. 4 or 5.

Mr. Glascott says—"The fermented bones far exceed my expectations, and I purpose sowing next season six or seven acres, with twelve bushels of fermented bones and two cwt. of guano to the acre."

The results of these experiments would certainly appear very favorable to the employment of fermented in preference to vitriolized bones; but they will scarcely be regarded as conclusive until some experimentalist on the large scale, like Mr. Lawes, shall have made such a number of comparative trials as will establish, beyond cavil, the relative value of steamed,† fermented, and vitriolized bones.

ADULTERATION OF VITRIOLIZED BONES.

The composition of commercial superphosphate of lime, even when not adulterated, varies exceedingly; some specimens, for example, containing but a trace of nitrogen, whilst

* This economical (?) manure sold, and, I believe, is yet selling, at £12 per ton. It contained about 35 per cent. of water, 25 per cent. of green vitriol, 15 per cent. of sulphate of soda, a *trace* of ammonia, and *no phosphoric acid!!* *Surely* it WAS an *economical* manure——to the manufacturer.—AUTHOR.

† Bones subjected to the action of high pressure steam have been found to decompose rapidly in the soil; and, according to some agriculturists, their effects are not inferior to vitriolized bones. Mr. Blackall was the first to propose this method of treating bones for agricultural purposes.

in others is found so much as four per cent. of this element. This is what we might expect when we consider that the article is prepared from one or more of the following substances:—Bones, bone ash, animal charcoal, coprolites, (fossil animal excrement,) apatite, and inferior phosphatic guanos.

The best descriptions of superphosphate of lime are prepared from well ground bones, freed from fatty matter. They should contain from 1 to 2 per cent. of nitrogen, and about 30 per cent. of phosphate of lime, of which, *at least*, one-half should be in a soluble condition.

When unadulterated specimens of superphosphate of lime differ widely in composition, what must not be the degrees of variance in those which are sophisticated! Many samples sold under the name of superphosphate of lime which I have examined were adulterated to such an extent as to render them almost worthless. Some contained from 40 to 60 per cent. of gypsum, others a considerable quantity of sandy matter, soap-boilers' waste, &c., whilst many contained no superphosphate of lime at all! These latter were in general composed of steamed bones, mixed with burnt gypsum (plaster of Paris).

Unfortunately, there is no simple method known whereby farmers can themselves detect the above-mentioned adulterations. It is only by an accurate chemical analysis that such frauds can be brought to light. The farmer, therefore, cannot be over cautious in making his purchases, which ought only to be made from manufacturers of established reputation; and should he have reason to suspect that a spurious article has been palmed upon him, he should at once call in the "detective" functions of chemical science to his assistance, and have the adulteration, and, if possible, the adulterator, "detected."

In the following table are shown the results of four analyses of superphosphate of lime, which I made last season:—

	1	2	3	4
Water	18·14	17·38	16·22	17·14
Organic matter and Salts of Ammonia	17·11	25·49	10·69	18·13
Yielding Ammonia ...	(2·875)	(5·110)	(0·88)	(2·132)
Biphosphate of Lime	12·57	10·20	3·19	—
Equal to Bone Phosphate, rendered soluble ...	(19·60)	(16·06)	(4·97)	
Insoluble Phosphates of Lime and Magnesia	10·70	8·82	11·14	28·35
Carbonate of Lime	—	—	—	6·29
Hydrated Sulphate of Lime	33·22	29·63	18·76	—
Burnt Gypsum	—	—	34·10	20·08
Alkaline Sulphates	3·88	3·96	1·88	1·10
Common Salt	—	—	—	4·21
Insoluble matter	4·38	4·52	4·62	4·70
	100·00	100·00	100·00	100·00
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Calculated value per ton ...	6 19 11½	7 5 0½	2 18 0	3 8 7

No. 1. (Ritchie's) This may be regarded as an average sample of good superphosphate of lime.

No. 2. (M'Kenny's) This specimen contained, in addition to a due proportion of earthy phosphates, an unusually large amount of ammonia. This was due probably to the admixture of ammoniacal salts, which are added by many manufacturers with the view of approximating the composition of superphosphate of lime to that of guano.

No. 3. This was a grossly adulterated sample, containing more than 40 per cent. of gypsum.

No. 4. This sample was composed of steamed bones, burnt gypsum, and common salt.

APPLICATION OF VITRIOLIZED BONES.

From the large amount of phosphoric acid which they contain, vitriolised bones are a most valuable manure for turnips, mangel wurzel, parsnips, and carrots. When har-

rowed in with the seed they are sometimes found advantageous to the cereals; yet, as these plants require a considerable amount of nitrogen, of which element vitriolized bones possess but a very small amount, they are scarcely a suitable manure for such crops, unless employed in conjunction with nitrate of soda, Peruvian guano, or other nitrogenous manures.

The quantity of vitriolized bones to be used must, of course, depend very much on local circumstances; but generally 5 cwt. per statute acre will be about sufficient for the above-mentioned root crops; or with 12 tons of farm-yard manure, say 2 or 2½ cwt. will, in most cases, be sufficient. For potatoes 6 cwt. per acre will not be too much, whilst for beans and other leguminous plants, 4 cwt. will suffice.

It should be borne in mind that the subsequent crop of wheat, clover, or grass is better after the use of the natural and artificial manures combined, so that when no farm-yard manure is used with the root crop, the crop which succeeds it should be specially manured, and, if possible, with a fertilizer containing a considerable proportion of organic matter.

Vitriolized bones ought to be thoroughly mixed with four or five times their own weight of turf mould, or finely sifted earth, before being applied: when used as a top-dressing for cereal or grass crops humid or showery weather ought, if possible, to be chosen for their application, so as to ensure their being well washed in and equably distributed through the soil, for when applied in dry weather they are apt to lie on the surface, affording to the plants but the trifling amount of fertilizing matters which the dew may happen to carry down.

Vitriolized bones are best applied as a top-dressing for cereals in spring, and soon after the plants have appeared over ground.

XII.—ON GUANO.

I.—ORIGIN AND NATURE OF GUANO.

PERHAPS the most important and remarkable event in the history of modern agriculture was the introduction into these countries of the curious substance known under the name of "guano." When this manure was first employed by a few experimenting farmers, the accounts which they published of its fertilizing properties were received with distrust by the great majority of the agricultural community. The superior virtues of farm-yard manure commanded their faith, and the announcement of another fertilizer of *forty* times the value of that primitive manure, instead of shaking, rather tended to support the belief which had so long rested on "every one's" experience. But a new experience was adduced, and the old, with its superincumbent opinions, had to give way, for the immense returns obtained from the application of guano to all kinds of crops became so evident that, in due time, all having any pretensions to be regarded as enlightened and prudent agriculturists were forced to acknowledge the importance of this most valuable and concentrated of manures.

The name guano is a corruption of the Peruvian word *huano*, signifying dung. The use of this substance as a manure was long known to the aborigines of Peru; and in so great estimation was it held as such, that the Incas—the native rulers—attached the penalty of death to the act of killing the "manufacturers" of the article—the sea-fowl which frequented the guano isles. The value of guano could not, indeed, be over estimated by the Peruvians; for without it, whole districts, in which maize and capsicums were successfully cultivated, would have been completely unproductive.

Since the introduction of guano from Peru into Europe deposits have been sought in every direction; and in meeting

the demand for it, several of considerable magnitude have already been exhausted. The coast of Peru has supplied the greatest quantity of guano. The coasts of Chili, Bolivia, Patagonia, Cuba, Labrador, and Australia have yielded supplies of greater or less magnitude, as have also the isles of Ichaboe, Malaga, Angra-Pequena, &c., near the Cape of Good Hope, and many other isles off the coast of Algiers, Arabia, &c., most of which have become generally known to us only since the discovery of their guano beds.

The total imports of guano into England from 1850 to 1854, inclusive, are set down in the last edition of the Encyclopedia Britannica as follow :—

1850,	116,925 tons.	1852,	129,889 tons.
1851,	243,014 „	1853,	123,166 „
	1854,	235,111 tons.	

The accuracy of the above figures has been questioned; but they may be regarded as being, at least, approximatively correct. The imports of guano for 1855, taken from the customs entries at the ports of England, were 143,136 tons of all sorts.

The opinion general among the importers and brokers of this article is, that at a fair price there is an annual demand for 250,000 tons of Peruvian, and 50,000 tons of other kinds; but for the five months ending 31st May, 1857, the returns give a total importation of only 60,423 tons, clearly showing what an opportunity was afforded to the manufacturers of spurious guano, and to what an amount of imposition the industrious and unsuspecting farmers were, in consequence, subjected to. To make up the deficiency which thus appears in the supply as compared with the demand, fraudulent vendors have repaired to their pits of clay, marl, &c.; and so successful have they been in their nefarious manufacture and traffic, that it is estimated the quantity of manure sold last

season, under the name of guano, was nearly double the amount of the genuine article imported!

Guano is formed of the bodies and altered egesta of sea-fowl.* Its composition varies considerably; the Peruvian variety usually containing a large proportion of nitrogen, whilst other kinds are almost destitute of this important element.

The following complete analysis of a yellowish brown guano, made by Oellacher, is here given for the purpose of showing the constitution of this peculiar substance:—

Sal Ammoniac	2·25
Urate of Ammonia	12·20
Oxalate „	17·78
Phosphate „	6·90
Carbonate „	0·80
Humate „	1·06
Ammoniaco-Phosphate of Magnesia	11·68
Phosphate of Lime	20·16
Carbonate of Lime	1·65
Oxalate of Lime	1·80
Chloride of Sodium	0·40
Sulphate of Soda	4·92
Sulphate of Potash	4·00
Waxy matter	0·75
Sand	1·68
Water	4·31
Undetermined organic matter ...	8·26
	100·00

II.—PERUVIAN GUANO.

The Chinchas Islands, from which the greater portion of Peruvian guano is obtained, are situated in latitude 13° 44′ S., longitude 76° 13′ W. They are three in number, and very

* Dr. Kinahan, in a paper on the Chinchas Islands, published in the Journal of the Royal Dublin Society for July, 1856, advances the opinion that the guano deposits on those islands are formed chiefly of the *debris* of seals. This opinion he supports by very forcible arguments.

small, the largest not being more than three miles in circumference; yet the deposits of guano on them are immense. M'Intosh, in his report to the Admiralty, estimates the quantity at 8,600,000 tons. The Peruvian survey sets it down at 18,250,000 tons. Dr. Kinahan estimates it at from 15 to 20,000,000 tons; whilst others say from 100 to 150,000,000 tons. In 1854 they supplied about 650,000 tons of this valuable manure, of which by far the greater proportion was landed in England and the United States.

In the Chinchas Islands, nature seems to prepare and preserve the valuable excrements of birds by means almost identical with those which the Chinese employ for the preservation of human fæces. Being in a hot and rainless region, the moisture which is essential to the ultimate decomposition of animal matter is carried away by the dry air, and the fæcal deposits may be said to be actually baked and laid up for use in a state and place in which decomposition is scarcely possible.

Good Peruvian guano should contain from 20 to 24 per cent. of phosphates of lime and magnesia, 15 to 20 per cent. of ammonia, and from 7 to 10 per cent. of alkaline salts.

The following analyses of six samples were made last season :—

ANALYSES OF GUANO SOLD AS PERUVIAN.

	1	2	3	4	5	6
Water	18·10	18·12	22·64	14·52	9·40	8·16
Organic matter and Salts of Ammonia ...	54·18	50·08	48·76	57·47	13·56	16·31
Yielding Ammonia ...	(19·08)	(16·20)	(15·32)	(17·24)	(3·86)	(2·84)
Earthy Phosphates ...	22·32	20·27	17·69	20·14	16·03	12·99
Carbonate of Lime	—	—	—	0·76	28·30	12·07
Alkaline Salts	9·17	9·16	8·67	6·48	4·19	4·53
Silica, Alumina, Peroxide of Iron, &c. ...	1·23	1·21	1·40	0·63	28·52	45·94
	100·00	100·00	100·00	100·00	100·00	100·00

Nos. 1, 2, 3, *and* 4 *were genuine Peruvian. Nos.* 5 *and* 6 *were largely adulterated with clay, &c.*

In 32 analyses of genuine Peruvian guano made by Professor Way in 1847, 1848, and 1849, the average amounts of ammonia, alkaline salts, and earthy phosphates are thus stated:—

Ammonia	17·41	per cent.
Alkaline salts	8·71	„
Earthy phosphates	24·12	„

In 6 analyses made by the same chemist in 1854 the

Average ammonia was	16·88	per cent.
Earthy phosphates ...	22·29	„

Professor Way gives as the mean of 78 analyses made by him since 1852—

Ammonia	16·52	per cent.
Earthy phosphates	22·78	„

In 16 analyses of real Peruvian guano performed by Dr. Apjohn in 1852, 1853, and 1854, the average amount of

Ammonia was	16·20	per cent.
Of earthy phosphates	22·16	„

In 12 analyses of genuine Peruvian guano, made by the Author in the present year, the average amounts of ammonia, phosphates, &c., stand thus:—

Ammonia	15·95	per cent.
Earthy phosphates	22·00	„
Alkaline salts	7·98	„

These average results show that Peruvian guano is undergoing a slight depreciation in the amounts of its most important constituents.

Peruvian guano can only be procured through a single English firm, Messrs. Gibbs, Bright, and Co., of London and Liverpool, who, by contract with the Peruvian government, enjoy a monopoly in the sale of this article.

III.—PHOSPHO-PERUVIAN GUANO.

The base of this valuable manure is what has been termed a "Pyro-guanite," found on the surface of a group of trap rock islets, within the tropics. It occurs as a dense, hard substance, in masses arranged in concentric layers, and consisting principally of a phosphate of lime, containing one equivalent less of base than is found in the phosphate of lime existing in bones or in other varieties of guano. Hence the facility with which the importers have been able, with a small quantity of sulphuric acid, to convert the phosphate of lime into a soluble super-salt.

The excellence of Phospho-Peruvian guano, as an artificial manure, will be obvious if compared with inferior phosphatic guanos and other manures made from bones, coprolites, apatite, &c. For every 10 per cent. of soluble phosphates in these, there are found, at least, 30 per cent. of hydrated sulphate of lime, whilst a considerable quantity of water and other materials, of little or no value as fertilizers, are necessarily added in the process of manufacture. To obtain from any one of these materials an amount of soluble phosphate of lime equal to that yielded by the Phospho-Peruvian guano—nearly 20 per cent., there would be produced about 70 per cent. of hydrated sulphate of lime, in contrast with only 25 per cent. in the other case.

Phospho-Peruvian guano is said to contain, in its natural state, from 30 to 35 per cent. of anhydrous phosphoric acid, in combination with from 30 to 40 per cent. of lime, magnesia, potash, soda, and ammonia. This is nearly double the quantity of phosphoric acid found in bones and other substances, from which the superphosphates usually sold are prepared.

In the Phospho-Peruvian guano there is an average of 50 per cent. of phosphate of lime; nearly one-half of which is rendered soluble by the addition of about 10 per cent. of

sulphuric acid, and the remainder is naturally more soluble than the ordinary bone phosphate.

It is not a little curious that Dr. Voelcker's and my own analyses of this guano, made about the same time, almost exactly coincide. I found it to consist in 100 parts of:—

Water		13·17
Organic matter and ammoniacal salts		13·25
Yielding ammonia	3·89	
And phosphoric acid, equal to soluble phosphate of lime	2·68	
Biphosphate of lime		14·08
Equal to bone phosphate rendered soluble ...	21·96	
Bone phosphate of lime		18·26
Phosphate of magnesia		2·75
Hydrated sulphate of lime		25·66
Salts of soda		5·50
Salts of potash		2·18
Silicious matter		5·15
		100·00

Doctor Voelcker's analysis gave in 100 parts:—

Moisture		13·67
*Organic matter and ammoniacal salts		11·97
Soluble or biphosphate of lime		12·58
Equal to bone earth rendered soluble ...	19·62	
Insoluble phosphate of lime (bone earth)		21·46
Hydrated sulphate of lime...		26·74
Alkaline salts		7·65
Containing phosphoric acid	4·01	
Equal to biphosphate of lime	5·57	
Insoluble silicious matter		5·93

*Containing nitrogen, 2·89, equal to ammonia, 3.51.

Dr. Voelcker sums up as follows:—

This manure contains—	
Bone earth rendered soluble by acid	19·62
The per centage of phosphoric acid in alkaline salts is equal to—Bone earth rendered soluble by acid	8·63
Insoluble phosphates	21·46
Total amount of phosphates calculated as tribasic phosphate of lime	49·71

Dr. Voelcker, an eminent authority in these matters, says—

"It deserves to be more generally known that Peruvian guano (Gibbs'), except in particular cases, is not the most desirable fertilizer that can by itself be applied to root crops, since it contains too much ammoniacal organic matter in relation to phosphates. The Phospho-Peruvian guano being much richer in phosphates, and not containing so much ammonia as to cause too luxuriant a development of leaves, at the expense of the bulb, is much superior to Peruvian guano (Gibbs') as a manure for turnips, Swedes, mangels, and potatoes; and I have, indeed, no hesitation in expressing the opinion, that for root crops the manure which I analyzed is by far the most valuable fertilizer, whether natural or artificial, which as yet has been offered to the public."

The composition of Phospho-Peruvian guano would seem to obviate all the objections ever urged against the free use of artificial manures, for it contains in just proportions all the ingredients requisite for the rapid and healthy development of all our cultivated plants.

It is to be hoped that the company to whose enterprising spirit the country is indebted for so valuable an adjunct to the means of scientific and profitable farming, will extend their operations so as to ensure a supply equal to the demands which their past exertions have created, and which, doubtless, science and practical good sense will continue to increase.

Let us also hope that what is thus proved to be of benefit to the farmer, and to the teeming population, depending upon him for a supply of food, will yield a corresponding reward to those who have opened up so valuable a mine of general wealth.

For much of the foregoing information I am indebted to Messrs. Dixon and Co., of Liverpool, Agents to the Phospho-Peruvian Guano Company, and to Messrs. George Seagrave and Co., of the same city, the Brokers to the Company.

IV.—PHOSPHATIC GUANOS.

Gibbs' Peruvian guano is the only variety at present imported which contains a large proportion of nitrogen. Most of the other kinds are valuable chiefly for their phosphate of lime and alkaline salts, but more especially for the former. It is, however, unfortunately the case that most of the phosphatic guanos imported are very inferior in quality, and although offered at a lower rate than either the Peruvian or Phospho-Peruvian varieties, the difference in price is by no means proportionate to their relative inferiority.

Many samples of the inferior phosphatic guanos which I have examined consisted, for the most part, of a mixture of earth, or of carbonate of lime, with a little bird dung, or phosphate of lime, from which the soluble fertilizing matters, associated with it in good guano, had been washed away by rain.

The following table exhibits the average composition of nearly all the phosphatic guanos at present imported into England :—

ANALYSES OF DIFFERENT KINDS OF PHOSPHATIC GUANO.

	1	2	3	4	5	6
	Upper Peruvian.	Ichaboe.	Bird Island.	Cuban.	Kooria Mooria.	Patagonian.
Water	10·00	20·00	15·00	26·00	18·10	25·00
Organic matter	21·68	24·40	6·50	4·10	12·41	18·30
Yielding Ammonia ...	(4·50)	(6·00)	—	—	(2·05)	(2·00)
Earthy Phosphates	51·50	20·40	37·25	43·70	42·67	44·00
Carbonate of Lime	—	—	40·00	24·10	4·19	—
Alkaline Salts	14·12	6·20	1·15	—	4·13	2·10
Sand, clay, and other useless matter	2·70	29·00	0·10	2·10	18·50	10·60
	100·00	100·00	100·00	100·00	100·00	100·00

No. 1.—UPPER PERUVIAN GUANO, imported by the Messrs.

Ravenscroft, and formerly sold under the name of "Bolivian guano," is obtained from the promontories on the coast of Bolivia. Its composition varies somewhat, depending upon the latitude in which it is found. The use of this guano has not generally proved very satisfactory. The analysis of it would seem, however, to indicate that it is a good manure for root crops, and it is probable that its effects would be greatly promoted were its very insoluble phospate of lime rendered more immediately available by the action of sulphuric acid.

No. 2.—ICHABOE GUANO.—The analysis refers to the recently worked deposits on the islands, which are said to have supplied last year about 2,000 tons, of which 1,000 tons were used in the Mauritius, and the remainder in Great Britain. The guano is collected by Seawright and Co., of the Cape of Good Hope, who send it to Liverpool for sale.

The odor of Ichaboe guano is remarkably pungent, and is, therefore, much prized by fraudulent dealers; a very small quantity of it being sufficient to give "flavor" to a large amount of marl, limestone, clay, or other equally worthless substances.

No. 3.—BIRD ISLAND GUANO is gathered from the coral reefs in the Gulf of Mexico, near the West India Islands. The adulterators mix it with damaged Peruvian guano, which confers on it a strong odor, a high recommendation to the farmer!

No. 4.—CUBAN GUANO.—The analysis refers to a cargo recently imported from the Pedro Keys reefs, south of Cuba. The deposits on these reefs are free to all comers, on payment of a royalty of £1 per ton to the Spanish government. This, together with about £1 for loading, and £2 10s. freight, will make a total of £4 10s. per ton. At this rate the guano would be a great boon to the agricultural public if it were

even moderately good, but the cargo which has arrived is too much like the Mexican variety, and, therefore, but of little value. It is altogether destitute of ammonia, and appears to be composed of phosphate of lime and decayed coral rock.

No. 5.—KOORIA MOORIA.—The analysis in the table shows the average of the results of four examinations of this variety of guano. These results indicate that it strongly resembles in composition the guano which is occasionally imported from islands in the Red Sea, and which has been pronounced of very little value.

Messrs. Ord, Hindson, and Hayes, the lessees under government of the Kooria Mooria Islands, state, however, that a portion of the guano deposits on these islands is but little inferior to the Chinchas guano; and that the cargo per "Colchester," which proved of such inferior quality, was not, as stated, obtained from Kooria Mooria, but from "Burnt Island," distant a thousand miles from the former.

No. 6.—PATAGONIAN GUANO of recent importation, as will readily be seen from the analysis, is by no means a valuable variety. Guano of similarly low value occasionally arrives from Chili, St. Helena, &c.; but, like the Patagonian, is sold with great difficulty at from 60s. to 90s. per ton; and as the proceeds of sale will seldom cover the charges it must soon cease to be an article of commerce.

I would strongly urge upon the farmer not to purchase guano offered at a low price. *Good* guano, like any other *good* article for which there exits a demand, is *never* sold at a low rate. Too often the employment of the inferior priced guano results in disappointment to the farmer: not only does he lose the price of the manure, but, what is far worse, the crop, which, were the guano good, he should have obtained. It is not, indeed, too much to say that most of the low priced guanos are dearly bought at any price.

V.—ADULTERATION OF GUANO.

There is, perhaps, no article of which large quantities are sold more liable to adulteration than guano. Demand and supply, of course, act on each other. The limited supply, the consequent high price of the article, and the avidity with which purchasers take the bait of cheapness are, no doubt, the combined causes of the extensive practice of sophistication. It may be said that the demand is greater than the natural supply. Men whose ingenuity and avarice are more extensive than their consciences step in and supply, or affect to supply, the deficiency; and as the addition which they make to the stock costs little, and is worth less, they are safe in offering it at a price so low as in most instances to be irresistible in its attractions to the confiding farmer.

The substances with which guano is adulterated are sand, clay, powdered bricks, marl, chalk, limestone, salt, &c., one or more of these being added to guano, generally to the strong smelling Ichaboe or damaged Peruvian, the proportions, of course, depending upon the conscience of the compounder, and on the presumed gullibility of the purchaser. So skilfully are these compounds prepared, that the most experienced buyers are often imposed upon, detection in very many cases being very difficult by any except chemical means.

The actual money value of guano can alone be ascertained by an accurate analysis, the performance of which requires considerable chemical knowledge and skilful manipulation; still, there are a few easy tests by which persons totally unused to chemical manipulations may detect at least the gross adulterations by which the honest farmer is so often victimized. The following easily performed tests apply to Gibbs' Peruvian guano:—

1. Peruvian guano, when pure, is of an uniform light gray color, and contains small lumps, which, when broken, are

found to be of a lighter hue, and generally of a crystalline structure. When the guano is dark and coherent, the probability is that it contains a large proportion of water. The amount of this useless constituent of guano may be determined by the following process:—Take 25 grains of the sample, and, for the purpose of fixing any free ammonia which it may contain, add one or two drops of sulphuric acid, place the whole on a sheet of paper, and expose it to a degree of heat sufficient to evaporate the water, but not to char the paper; the heat to be continued until the sample ceases to lose weight. The weight lost in drying, multiplied by 4, gives the per centage of water. A still better way of drying the guano is by means of the water bath, a convenient form of which consists simply of a capsule or a small saucer placed on a saucepan of boiling water.

2. To ascertain the amount of organic matter and ammoniacal salts in the sample, put the dried guano into a small porcelain crucible or capsule, heat the crucible gradually on the hob, then place it on the embers of a clear fire, and heat it to redness; keep it at that temperature for about 20 minutes, or until the black color first assumed by the guano has disappeared, and nothing remains but ashes. To save the crucible from being cracked by a sudden change of temperature allow it to cool gradually. Multiply the weight lost in the crucible by 4, and after subtracting the weight of the acid added in the first operation, the result will be the percentage of organic matter and ammoniacal salts.

By burning, the most valuable portion of the guano is removed; by drying, most of the useless: by both together, the loss in the weight of Peruvian guano should be about 60 per cent. If the loss be much less, either the guano is naturally inferior, or it has been adulterated, which, it matters little to the farmer. The color of the residue is of importance;

that of pure guano is invariably white, whilst the ash of the adulterated specimens is generally of a brown or reddish brown color.

3. The next step will be to mix the residue of the burnt guano in a capsule or cup, with a table spoonful of muriatic acid, and three or four times that quantity of water. The escape of two or three bubbles of gas need not be heeded, as pure guano occasionally contains a trace of carbonate of lime; but if the acid causes a violent effervescence or bubbling of gas, such as is observed in the mixing of a seidlitz powder, the guano has been adulterated with chalk, limestone, or marl. If the residue be considerable, and that there is no effervescence, the capsule, with its contents, may be placed on the hob for about half an hour, and then allowed to rest; after which the clear liquor is decanted, and the residue, having been well washed with water, is placed on a sheet of paper, supported on a pad of blotting paper, and dried on the hob or in an oven. The weight of what thus remains, multiplied by 4, gives the per-centage of the insoluble earthy or silicious matters, which are of no value whatever. If the residue is large in quantity, of a whitish color, and only soluble by long continued boiling in muriatic acid, the guano is, in all probability, adulterated with gypsum.

4. A teaspoonful of a sample of good guano, mixed with an equal quantity of cream of lime, will develop a powerful ammoniacal odor, similar to that of Bengal or smelling salts. The pungency of the odor will be proportionate to the amount of ammonia in the sample. The success of this test depends upon the quality of the quicklime employed; it ought to be of recent burning, or to have been preserved in a close vessel, as on exposure to the air it absorbs carbonic acid, and passes into the state of carbonate, in which condition it is no test for ammonia.

5. Guano is sometimes, though rarely, adulterated with common salt. By a close examination of the suspected sample, the grains of salt will be readily seen, and may be picked out and tasted.

6. A bushel of guano, if pure, weighs almost exactly 70 lbs.; if adulterated with light substances (which is rarely the case) it will, of course, weigh less. If clay, marl, sand, &c., have been used, the weight will be materially increased, and so far as this test applies gross adulterations will be easily detected.

To sum up—

1st—By drying and burning, Gibbs' Peruvian guano should lose from 55 to 60 per cent. of its weight.

2nd—Its ash should be white, and should dissolve readily, and without effervescence, in dilute muriatic acid, leaving—

3rd—Insoluble residue, which should not amount to more than 2 per cent. of the weight of the guano.

4th—Mixed with quicklime it should give out a strong ammoniacal odor.

TESTS FOR PHOSPHO-PERUVIAN GUANO.

a. 100 grains lose, by drying, from 9 to 14 grains, and by both drying and burning from 25 to 32 grains.

b. The ash is white, and does not effervesce with strong vinegar.

c. The ash of 50 grains dissolves by long continued boiling in muriatic acid, leaving a residue of not more than 3½ grains.

For the adulterations of the inferior phosphatic guanos there are no satisfactory tests which could be performed by those unacquainted with chemical processes. The ashes of the best samples are light colored, do not effervesce much with acids, and do not leave a very large residue after treatment with warm muriatic acid.

VI.—APPLICATION OF GUANO.

For turnips, parsnips, carrots, and beans, about 4 cwt. per statute acre of Peruvian guano are necessary, whilst mangel wurzel and potatoes will take 6 cwt. To potatoes it is better to apply a moiety at the time of setting, and the rest at the second earthing; as, when applied altogether, it is expended in producing too great a growth of the haulm, and leaving too little for sustaining and maturing the crop. Of Phospho-Peruvian guano a smaller quantity will suffice, owing to its large amount of phosphoric acid, which renders it a manure much superior to Gibbs' Peruvian guano for all kinds of root crops.

For grass crops, a top-dressing of 1 to 1½ cwt. of guano, per statute acre, produces the most marked and rapid effects. In two or three days the grass assumes a rich dark green hue, the growth of the plants is accelerated, and the meadows, natural or artificial, are brought early to perfection. As dry weather is unfavorable, the beginning of April, which is generally showery, is, perhaps, the best time to apply guano as a top-dressing.

For the cerealia guano is, *par excellence, the* manure. The most luxuriant crops ever obtained have been those to which this manure had been applied. I have known one acre of wheat manured with good guano to be 50 per cent. more valuable than the produce of an acre manured from the farm-yard. From 2 to 3 cwt. of guano is generally applied to wheat, of which all, or the greater portion, may be used in the autumn.

Peruvian guano is an excellent manure for the cereals generally; but for barley, which is known to be benefitted by the application of manures containing a large amount of phosphoric acid, I would recommend Phospho-Peruvian guano in preference.

Peruvian guano when used *per se* for green crops is not so lasting in its effects as Phospho-Peruvian guano, bones, or vitriolized bones. The subsequent corn crops are seldom benefited much by it; although I have noticed some instances of its application to grass in which its effects were apparent for two or three years. When guano is employed in conjunction with farm-yard manure and vitriolized bones, the acme of manuring may be said to be attained; for whilst the green crop roots are more solid, more nutritious, and more easily preserved than when manured with guano alone, the after crops are as abundant as if the green crops had been manured from the farm-yard. It is, therefore, best, when practicable, to use guano and farm-yard manure together, 1 cwt. of the former being replaced by 7 or 8 tons of the latter.

Guano should be finely pulverized, and mixed with five or six times its weight of coal ashes, turf mould, or fine soil; it should be borne in mind when using guano, that if it comes in contact with the seeds, their vitality is instantly destroyed.

In Ireland, Scotland, and West of England, where the air is generally moist, and showers are of frequent occurrence, guano, as well as all other artificial manures, may be applied at almost any period of the year; but in the middle and East of England, and in other countries where there are long seasons of drought, humid weather should be selected for its application, as otherwise there is great danger of the crop being burned up.

Doctor Apjohn disapproves of the common practice of mixing guano with vitriolized bones, because the soluble phosphate of lime contained in the latter is rendered insoluble by the action of the former. I have, however, already shown that the soluble phosphate of lime is converted into the insoluble phosphate by mere admixture with the soil; so that, practically, the mixing of guano with vitriolized bones can only anticipate what would ultimately occur in any case.

XIII.—ON SEWAGE MANURE.

From guano to the liquid manure obtainable from our sewers the transition is easy and natural; for, whether we consider their origin or their value to the cultivator of the soil, they are very nearly related to each other. As regards their origin, I know that most of those acquainted with the commerce merely of such matters would be better prepared to trace a considerable proportion of the guano in the market to beds of ferrugenous clay in England, than to the sewers of Dublin and of other cities. For example, if there be any reason to believe that there exists some tangible connection of cause and effect between the contents of our sewers and the guano obtained from the opposite hemisphere, the question will naturally occur to the economist, why not employ the fertilizing substances so abundantly placed at our command at home, instead of ransacking remote parts of the globe for the same substances in another and more costly form? The easy-minded *optimist* disposes of the question summarily—that as we *do* obtain such substances under the form of guano, it *must* be the best.

I do not mean to assert that the identical lots of guano which are daily landed on our quays did actually pass down our river in another form; but I do say what is practically of equal importance, that the raw materials from which guano is prepared by the natural producers of that article are to be found every day in the rivers of all the cities in the world, and in such quantities as must appear incredible to those unaccustomed to reason on such matters. These materials, the contents of our sewers, are carried into the sea, and there furnish food for vast fields of marine plants. These plants, in their turn, go to support the teeming animal life of the ocean—the multiform denizens of the deep. Of these,

generation succeeds generation, and myriads of them, in ceasing to dwell in the "waters under the earth," become the food of birds which move in the "Heavens above." The excreta which these deposit in their resting places, and the bodies which they ultimately lay down in death, form accumulations similar to those enormous guano banks, which of late have become of such commercial importance throughout the entire civilized world—given so great an impetus to agricultural improvement—and so largely contributed to supply the demand for food of an increasing population.

This seems going a great distance for proof and illustration of the value of what lies or rather runs under our feet. The journey will not, however, be considered by any means too great, if the knowledge acquired is found in the end to have contributed in any measure to the realization of the practical truths involved in it. An important object is gained if it teach the citizen and farmer the advantages which both would derive from the direct application to our soil of those streams—rich in the *food of plants*, but fraught with poison to animals—which flow from the filthy veins of our cities, and are lost to us in the ocean.

From our anxiety to obtain guano from distant sources, and our carelessness in allowing the *elements* of guano to pass away from us, it would appear as if we supposed those elements were rendered infinitely more valuable by being passed through the bodies of animals; but in either case we possess simply disorganized animal matter.

The *post facto* advocates of our aggression upon China allege, as a grave and justifiable cause of war, that whilst we purchase their tea in such abundance, the Chinese will take nothing in exchange but money. From what we know of the economy of the *celestial* agriculturists, it would not astonish us much if, on hearing of our wilful waste of the valuable manure in our

sewers, they should enter into arrangements with our merchants to exchange the precious leaves for cargoes of that article. We should then have an opportunity of witnessing an extraordinary spectacle—two vessels side by side, one unloading guano from Peru, and the other shipping sewage manure and night soil to China. It may be that our descendants will be engaged in another Chinese war, justified on the grounds of the subjects of the "Uncle of the moon" taking away our most valuable manure, and refusing us tea on any other terms!!

But to learn the value of our sewage as a manure we do not require to visit Peru, or wait until the natives of the "flowery land" have shown us an example in the use of it. Edinburgh, which is so peculiarly situated with respect to the adjacent country, furnishes us with, perhaps, one of the best practical examples of the use of this article as a fertilizer of the soil.

Thousands of the readers of Scott's novels have visited the site of the residence of Jeanie and Effie Deans, immortalized in the *Heart of Mid-Lothian*, and traversed the demesne of the whilom "Laird of Dumbiedikes," in that margin of the "old town" which faces the Salisbury Crags. A considerable portion of the excess of water of the ground in this part of the city naturally traverses the Dumbiedikes, and runs into the valley* at the foot of the Crags. As a consequence, the sewage takes the same course. As there is not a river in the valley we might naturally expect to meet with a stagnant pool, that fruitful source of malaria. This, however, is not the case. The sagacity which has placed the Scotch amongst the first agriculturists of the day suggested to the citizens of the "Modern Athens" that the liquids which would have formed such a pool might be better employed

* This valley now forms part of the King's Park, and the sewage is carried a mile further to irrigate the meadows at Restalrig.

in fertilizing the soil; they were, accordingly, caused to irrigate the adjacent land, and the result was the production of crops of hay, not only of excellent quality, but in such numbers as must be regarded as incredible, unless actually witnessed. Seven and eight crops were not uncommon, and even so many as ten have been raised in one brief season of a northern climate.

Some years since the sewage of Edinburgh was conducted to land by the sea side, in the vicinity of Portobello, a few miles below the city, and although previously this land had been entirely unproductive, it was in consequence of this application rendered capable of producing abundant crops of the best description.

The fall of the ground from Edinburgh affords a declivity sufficient to carry the contents of the sewers into a main drain along the head of the land, from which, by small arteries judiciously disposed, the sewage is distributed over the whole ground, affording an abundant supply of the food of plants.*

In these cases we have sewage and drainage manure applied at a comparatively small cost. It undergoes no preparation, and requires no machinery to carry it to its destination. In such cities as Edinburgh, the inclination of the land towards the country will always afford a sufficient natural conveyance for sewage; but in other cities, not so favorably situated, no

* According to Professor Anderson 10,000 gallons of the sewage water of Edinburgh, taken from the mouth of the sewer as it flows upon the irrigated meadows at Lochend, contain:—

	lbs.	Value s.	d.
Ammonia	11·0	5	6
Potash	4·1	0	9
Phosphoric acid	8·8	1	1
Total		7	4

obstacle should be permitted to prevent the free and general use of this valuable manure. Advantages like those possessed by Edinburgh are, no doubt, of great importance in connection with the appropriation of this manure, and it becomes a question for practical consideration how, in towns situated like Dublin, having no elevation above the surrounding country, the difficulties in the way of the distribution of the sewage over the adjacent land is to be overcome. It may, however, be stated, and this comes properly within the sphere of the *Chemistry of Agriculture*, that the obstacles which prevent the application of this manure, abounding as it does within a few miles of the soil which hungers for it, are surmountable, that they must yield before a little practical energy, and then we shall have such flourishing results as I have described as arising from the employment of the Edinburgh sewage.

The encouraging fact that land at Portobello which formerly brought but from four to five shillings per acre now commands from twenty to thirty pounds, should operate as a powerful incentive to our adopting the necessary means to apply a manure alike so valuable and abundant. The chemist has already, by analysis, ascertained its properties; the agriculturist has practically demonstrated the value of its application;* and it now only remains to decide upon the means by

* Mr. Tuffnell, inspector of schools, in his report on the North Surrey District School, containing 800 souls, gives some interesting information relative to the use of sewage manure, which cannot be too widely disseminated. This gentleman reports—

"In connection with this school is a farm, to which the sewage and solid refuse of the school was applied after filtration. The filtering material consisted of peat charcoal and burned clay, after passing through which the sewage flowed away in the form of odorless water. The agricultural superintendent of the school reports as follows on the use of this sewage:—

"'In November, 1855, I sowed three quarters of an acre of Italian rye-grass. It was flooded during the winter with sewage, and on the 27th of April, 1856, it was begun to be cut. From that day to the last day

which it can best be conveyed to places unfavored by position as regards the elevation of towns. It thus becomes a matter of reciprocal interest between the agriculturist and the citizen. The former will, no doubt, gain largely by the use of the sewage, and the latter by its removal will derive advantages, which, in a sanitary point of view, cannot be over estimated.

To achieve ends so desirable, surely the engineering expenses should not for a moment be regarded as an obstacle; even considerable outlay might be made with a positive certainty of large returns within a short period. The variety and magnitude of the enterprizes which occupy the public attention may, perhaps, have operated against the sewage question being entertained by cautious capitalists. The banks of England and Ireland, steam packet companies,

of October we cut one cart-load of green food every day, weighing about a ton. The part of the ground that was cut was always flooded with liquid manure immediately after the grass had been carted away.'

"'Then the produce amounted to *two hundred and thirty-five tons of green food per acre?*' 'Yes, the grass stood two feet six inches high; sixteen head of dairy stock and one horse were fed on it during that time; the horse had two bushels of oats a week, and the cows a daily run of four hours on five acres of pasturage, besides the Italian rye-grass, but nothing else was given them during that period.'"

The results of the use of the solid manure on the farm were equally remarkable, both as to economy and productiveness. Mr. Tuffnell continues:—

"'Supposing the filtering tank to be filled with four tons of burned clay and a quarter of a ton of peat charcoal, the cost would be £1 8s. 9d., and this would produce 8 tons of manure, worth £4.' 'Yes; that is a fair approximation.'

"'To what crop has the manure been applied?' 'Mangel wurzel and potatoes. The Swedes and mangel wurzel produced 25 tons per acre, and I do not know the quantity of potatoes. Wheat, in each case, was sown after the roots, and the produce has generally been five quarters an acre, except when guano was used, when the crop was considerably lighter, both in straw and corn. The yield of wheat was about equal from the ground, where the sewage manure and farm manure had been used, but much more straw in the latter case.'"

railways, and other great projects, engross the attention, as well as require a large amount of the capital of the United Kingdom. But while many of these gigantic schemes afford safe and profitable investments, public companies formed for the purpose of supplying the sewage of large towns to farmers would prove equally—perhaps more—remunerative, whilst, on the other hand, an incalculable amount of good would be conferred upon the agricultural community.

The following calculations will show the enormous loss which the public at large sustains by the waste of our sewage :—

The quantity of excrements passed by each individual, averaging both sexes and all ages, is—

Of urine, daily, 2 lbs. ; yearly, 730 lbs.

Of fæces, daily, 3 oz. ; yearly, 31 lbs. (nearly).

Assuming the population of Dublin and its suburbs to be, in round numbers, 300,000, there will be annually produced—

	lbs.	£	s.	d.
Of URINE	219,000,000			
Containing nitrogen ...	2,190,000, at 8d. per lb.	73,000	0	0
,, Soluble Phosphoric acid	328,500, at 5d. per lb.	6,843	15	0
,, Salts of potash ...	657,000, at 1½d. per lb.	4,106	5	0
,, Salts of soda ...	1,752,000, at 30s per ton	1,173	4	3
Of FÆCES ...	9,300,000			
Containing nitrogen ...	66,400, at 8d. per lb.	2,213	6	8
,, Insoluble Phosphoric acid ...	66,400, at 1½d. per lb.	415	0	0
,, Organic matter (deducting nitrogen)	2,092,300, at 10s. per ton	467	0	7½
	Total ...	£88,218	11	6½

The foregoing calculations are certainly not in excess, and if we take into consideration the excreta of horses and of other domestic animals, as also the soap suds, scullery refuse, &c., which find their way into our sewers, we may safely assume, without at all exaggerating, that the refuse animal matter of

Dublin is worth considerably more than £100,000 per annum, or nearly two-thirds the amount of the local taxation of the city, and the revenue of its corporation!

The above calculations also furnish us with some other interesting information of an important character; for instance, we learn from them that the entire amount of night soil produced annually in Dublin is worth little more than £3,000, whilst the value of the urine produced in the same period is upwards of £85,000, thus demonstrating that the fluid excrement of the population is nearly thirty times more valuable than the solid!

When the farmers and market gardeners in the vicinity of Dublin derive so much benefit from the application of the *small* quantity of the city night soil which they *do* use, what incalculable benefits would they not derive from the application of the *remainder* of the solid and *all* of the liquid excrements produced in the city!

It may interest the sanitary reformer as well as the scientific agriculturist to know the composition of that fluid which changes the pure and pellucid waters of the Liffey into a dark and lethal stream; I shall, therefore, conclude this chapter on sewage manure with the following analysis:—

100 tons of the sewage water of Dublin contain—

	lbs.	s.	d.
Nitrogen	16·0 worth	10	8
Phosphoric acid	4·2	1	4½
Salts of potash	5·1	0	7½
Salts of soda	14·2	0	2½
Organic matter	75·0	0	4
		13	2½

The sewage was collected at different parts of the city, and at various hours. The phosphoric acid I consider to be, according to present prices, worth 4d. per pound, as it exists in sewage for the most part in a soluble condition.

XIV.—NITROGENOUS MANURES.

I.—NITRE.

NITRATE of potash (saltpetre or nitre) and nitrate of soda (cubic, or Chili nitre) are employed, though to a limited extent, for manurial purposes. The consumption of nitrate of soda has of late been on the increase, whilst the nitrate of potash, from its high price, is gradually falling into disuse.

Saltpetre is found in India, Peru, and many other countries situated in various climates; but it is found in greatest abundance in the tropical regions. In the Pamba del Tamaragual, province of Tarapaca, Peru, vast deposits of saltpetre and nitrate of soda have been discovered, sufficient to supply the wants of Europe for a lengthened period.

Nitrate of potash and other nitrates are formed in soils by the slow decay of nitrogenous organic matter. Ammonia is in the first instance produced, and subsequently oxidized and converted into *nitric acid;* the lime or alkalis which may be present in the soil enter into combination with the acid and form nitrate of lime, or nitrate of potash, &c.

Nitric acid is also formed in the air by the *chemical* union of the constituents of the atmosphere—oxygen and nitrogen—brought about by electrical discharges. Rain water dissolves this acid, and carries it down into the soil, where, meeting with lime, &c., nitrates are produced.

These natural operations are most curious and interesting, and our ingenious neighbours, the French, closely studying the phenomenon of the natural production of the nitrates, have succeeded in forming artificial "nitre beds," for the purpose of generating this important substance, which is useful alike in peace and war.

Nitrate of soda is occasionally adulterated with common salt; but as the latter occurs in crystals of a whiter color

than the former, a close inspection will lead to its detection. Nitrate of soda, when pure, burns with a fine yellow flame; but when mixed with a rather large proportion of common salt it evolves a greenish light. The presence of Epsom salts, a substance occasionally used to adulterate nitrate of soda, may be readily detected by dissolving a portion of the suspected sample in distilled water, and adding to the solution thus prepared a solution of carbonate of soda, which, if Epsom salts be present, will cause an abundant white precipitate.

It is the opinion of most agriculturists that the nitrates contribute powerfully to the development of wheat and other varieties of crops, but by many they are esteemed a manure far inferior in *forcing* power to the ammoniacal combinations. The late Mr. Pusey strongly recommended the use of nitrate of soda as a fertilizing agent.

Nitrate of soda, mixed with its own weight of common salt, may be advantageously used as a top-dressing for meadows at the rate of from 1 to 1½ cwt. per statute acre.

In using the nitrates it should be borne in mind that nitrate of soda contains more acid, and, as a consequence, is much richer in nitrogen than saltpetre, besides being much cheaper. Indeed, the use of nitrate of potash is completely prohibited in these countries by its very high price—

Dry nitrate of potash contains 53·40 per cent. of nitric acid.
Dry nitrate of soda contains 63·53 ditto.

Nitrate of soda applied in moist weather will, in general, change the sickly yellow color which the growing wheat sometimes assumes into a rich and healthy green.

II.—WOOLLEN RAGS.

Woollen rags form an excellent manure for most crops, but they are more particularly employed for raising hops, for which purpose they are held in high estimation in the hop

growing counties of England. They are not, however, valuable for hops alone; their application might, with great advantage, be extended to wheat, flax, and other plants, requiring for their development a liberal supply of nitrogenous manure.

There are few substances richer in nitrogen than woollen rags; they contain nearly a sixth of their weight of this valuable element—a proportion little short of that found in the best specimens of Peruvian guano. On the other hand, they are remarkably deficient in the inorganic materials required by plants; they must, therefore, be considered as a special manure, capable of supplying abundantly the principal element of cultivated plants—nitrogen.

As woollen rags decompose very slowly in the ground they should be ploughed in four or five months before their fertilizing action is required; or, they may be rendered immediately available by acting upon them with about one-third their weight of sulphuric acid.

An excellent mode of speedily converting the insoluble nitrogen of rags into soluble ammonia is, causing them to undergo a smouldering combustion, and condensing the ammoniacal vapours given off by means of a suitable apparatus. This method has, I believe, been adopted at one or two manufactories, but it deserves to come into more general use amongst manufacturers of artificial manures.

In Kent, the county *par excellence* for growing hops, the rags are mixed with five or six times their weight of earth, and the compost kept constantly saturated with liquid manure. By these means a partial decomposition of the rags is effected, and a manure of great value obtained. In England rags are applied at the rate of from 10 to 20 cwt. per statute acre.

In Dublin woollen rags may be purchased from the dealers at about £2 5s. per ton, a moderate price enough, when we consider their agricultural value.

III.—AMMONIA AND ITS COMPOUNDS.

The *ammoniacal liquor* of gas works is a very valuable manurial substance; but I regret to say it is very often wasted, even in localities where ammoniacal manures in other forms bear a high price. Ammoniacal or gas liquor contains carbonate of ammonia, sal ammoniac, sulphide of ammonium, tarry matters, and small quantities of other unimportant substances. The amount of ammonia in the liquor varies considerably; some specimens containing little more than 1 per cent., whilst others have been found to contain so much as 8 per cent.

Diluted with three or four times its own volume of water, ammoniacal liquor may be applied with great advantage to grass or clover. It may also be added, with profit, to the compost heap, as it induces speedy fermentation in organic matters, such as turf, straw, &c., which have naturally but little tendency to decay.

Crude sulphate of ammonia is prepared by neutralizing the liquor of the gas works with sulphuric acid, and evaporating the solution to dryness; it contains about 24 per cent. of ammonia.

Sulphate of ammonia is occasionally adulterated with sulphate of soda (glauber salts). This adulteration, as well as others of a similar character, may be readily detected, by heating 100 grains of the sample to redness in any convenient vessel—a fire-shovel answers the purpose very well—when, if the sample be pure, it will be dissipated, leaving, at the most, a residue of 4 or 5 grains.

Sulphate of ammonia is an excellent top-dressing for spring wheat, clover, grass, and other crops. It should, however, be used sparingly with soils containing but little soluble mineral matter. A manure composed of sulphate of ammonia and fermented bones might be employed with advantage as a substitute for guano in many instances.

Sal ammoniac (chloride of ammonium), the impure salt prepared from gas liquor, is occasionally employed as a manure. It contains, when unadulterated, about 30 per cent. of ammonia, or double the amount of that substance found in Peruvian guano. Heated to redness, it should volatilise, leaving but a trifling residue. It is applied in the same way as the sulphate.

IV.—SOOT.

Soot consists of charcoal, salts of ammonia, gypsum, and other mineral substances, and various organic compounds, varying in their nature with the kind of fuel from which the soot was derived. The value of soot as a fertilizer depends almost altogether upon its amount of ammonia. I have found in some specimens but 1 per cent., and in others so much as 6½ per cent. of this valuable substance.

Soot may be used with any crop requiring nitrogen, but when applied to pasture land in spring, it is said to impart a bitterness to the grass; and it is further stated that the milk of cows fed on early grass which had been manured with soot possesses a disagreeable taste.

V.—BLOOD, HORN, HAIR, ET CETERA.

Blood has not yet come into general use as a manure in the United Kingdom. On the Continent, however, it is highly esteemed as such; and in France dried blood is an article of commerce, large quantities being exported to the colonies for manuring the sugar cane.

Blood contains about 3 per cent. of nitrogen, and a small proportion of phosphoric acid. Good samples of dried blood yield about 17 per cent. of ammonia, and so far as nitrogen is concerned, are fully equal to the best Peruvian guano. Properly dried blood is worth from £8 to £8 10s. per ton.

Horn shavings, *hair*, *feathers*, and *leather clippings* contain a considerable proportion of nitrogen, and would be very valuable manures but for their tendency to resist decomposition. They are, however, excellent additions to the compost heap; and, if treated as directed in the case of woollen rags, their fertilizing effects would be greatly promoted, and their value to the farmer proportionately increased.

VI.—OIL CAKE.

Oil cake is the residue of linseed, rape, and other seeds which have been subjected to pressure for the purpose of extracting their oil. The more completely the cake has been freed from the oil, the more suitable is it for manurial purposes; as the presence of the oily constituents retards the decay of the nitrogenous. 100 lbs. of oil cake contain about 6 lbs. of nitrogen, 3 lbs. of phosphoric acid, and 2 lbs. of alkalis.

I have placed oil cake under the head of nitrogenous manures, because I consider that its fertilizing effects are chiefly due to its nitrogen. As in the case of guano its action is immediate, and generally limited to the first year.

Oil cake is chiefly employed as a manure for wheat. It is drilled in with the seed, or used as a top-dressing in spring. When applied to turnips and potatoes it should be in conjunction with bone dust or farm-yard manure.

Some farmers apply their oil cake manure in a rather round-about, and, as I think, unscientific way. I allude to the practice of feeding farm animals with it for the sake of their excrements. There can be no objection to its being used as food when the object is the direct manufacture of beef or mutton; but it is simply waste of time and material to employ animals to manufacture a manure which is less in quantity and no better in quality than the material from which it is produced.

XV.—ON THE DETERMINATION OF THE MONEY VALUE OF MANURES.

No artificial manure should be bought without the buyer previously obtaining an analysis, setting forth its exact composition. Testimonials are seldom to be relied upon. In numberless cases the most worthless manures have been palmed upon the unsuspecting farmer by means of specious testimonials. A correct analysis can alone be depended upon; and even this, in not a few instances, proves unavailing. The analysis may be correct, but it is practically of no value to the farmer unless he understands it; and not only so, but a true statement of the composition of a bad specimen may, to him, appear that of a good one; and he may purchase the bad under the impression that as an analysis is given at all it is as a guarantee of the genuineness of the article. Relying upon this very natural mode of reasoning on the part of the purchaser, the fraudulent dealer resorts to this audacious expedient in order to avoid being prosecuted for selling otherwise than "according to the analysis." I am informed that an analysis made by myself of a perfectly worthless sample of guano was used last season, and with considerable success, actually to recommend an article which possessed no value whatever! So long as buyers are unacquainted with even the elementary principles of chemistry so long must we expect this system of imposition to be pursued. Let us hope, however, that this is a state of things which will not long continue. If fraud is abroad seeking for prey, science is on its track to discover and disarm it; and even the agricultural portion of the community, though so widely dispersed from the great urban centres of scientific light, cannot long remain in ignorance of that science which must be regarded as the

farmer's best friend and safeguard, and the true exponent of his noble art.

MONEY VALUE OF THE CONSTITUENTS OF MANURE.

		£	s.	d.
Nitrogen (insoluble)	per ton	56	0	0
Ammonia	„	56	0	0
Phosphate of lime	„	7	0	0
Phosphate of magnesia	„	7	0	0
Soluble or biphosphate of lime ...	„	28	0	0
Phosphoric acid (insoluble)	„	14	0	0
Phosphoric acid (soluble)	„	46	0	0
Sulphate of lime	„	1	10	0
Salts of potash (except the nitrate) ...	„	14	0	0
Nitrate of soda	„	22	0	0
Sulphate of soda	„	1	10	0
Common salt	„	1	5	0
Alkaline salts, when chiefly soda compounds	„	1	10	0
Organic matter	„	0	10	0

The above is a very close approximation to the true money value of the ingredients of manures; but, as prices fluctuate, in the lapse of time it may be found necessary to make alterations in the table. The principle, however, upon which it is constructed is applicable to all times.

There is always a certain quantity of alkaline phosphates to be found in good guano, and these being soluble their presence adds considerably to the value of the manure. The amount of acid should be ascertained, and its value estimated as soluble phosphoric acid.

The simplest method by which to determine the value of a given quantity of guano is that suggested by Mr. Nesbit. He makes the constituents of the manure, as given in the analysis, to represent 100 tons. The amount of each ingredient is multiplied by its price per ton, and all the products added together give the value of 100 tons. This result, of course, divided by 100 gives the value of 1 ton.

The following example shows how the value of a manure may be deduced from its analysis:—

VALUATION OF A SAMPLE OF PERUVIAN GUANO.

	Per centage of each ingredient.	Value per ton. £ s. d.	Total. £ s. d.
Water	16·81		
Organic matter ...	51·24	× 0 10 0	= 25 10 0
Phosphate of lime ...	22·76	× 7 0 0	= 161 0 0
Alkaline salts ...	7·13	× 1 0 0	= 10 10 0
Sand	2·56		
	100·00		
Ammonia	16·60	× 56 0 0	= 924 0 0
			£1121 0 0
			20
Value per ton, £11 4 0			4·20

A good deal of unnecessary complication may be avoided by disregarding all decimals in the analysis up to 25, reckoning those from 25 to 75 as 0·50, or a half per cent., and 75 and upwards as an additional unit. Thus, in the above example, the organic matter, which is 51·24, is reckoned as but 51, the ammonia, instead of 16·60, as 16·50, and the phosphate of lime instead of 22·76 as 23. Thus the loss on one ingredient of the manure is balanced by the gain on another, and an estimate sufficiently accurate for all practical purposes is arrived at.

APPENDIX.

ON UREA AS A DIRECT SOURCE OF NITROGEN TO VEGETATION.

READ BY THE AUTHOR, AT THE MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, HELD AT DUBLIN, AUGUST, MDCCCLVII.

In the progress of the science of agriculture we have arrived at a stage at which we understand the importance of affording to plants an abundant supply of liquid food. At this point the economic and scientific agriculturor and the sanitary reformer meet. The agriculturist wants liquid manure, and those who have the care of the health of the inhabitants of large towns wish to get rid of oceans of that article; and yet to any appreciable degree neither party has been accommodated.

There seem to be some two or three problems which must be solved ere this demand on the one hand, and the supply on the other, can be made—as we say in chemistry—to neutralize each other.

In the great laboratory of nature, the exchange of carbon and oxygen between plants and animals is carried on without labour, difficulty, or expense, and to the essential advantage of both. A similar exchange of the fruits of the earth for the liquid and solid refuse, with which mankind wishes to dispense, is only a question of time, and one which we shall, ere long, see among the recognized facts of advanced civilization.

How to dispose of the sewage of London and yet preserve the water of the Thames from pollution is well known to be

one of the great questions of the day. A similar one is now forcing itself upon the attention of the citizens of Glasgow, and what was, until lately, looked upon as a sanitary question has now become one of pounds, shillings, and pence to the shipping interests of that enterprising city. I find by the *Scotsman* of Saturday last that the passenger traffic of the Clyde is already injuriously affected by the noxious effluvia sent forth by the discharge into that river of the sewage of Glasgow. In Edinburgh the question assumes the alternatives of stopping the great Caledonian distillery or covering in the water of Leith—the Illissus of the "modern Athens."

In Portobello the inhabitants are desirous of having their sewage conveyed into the Firth of Forth; but those interested in the preservation of the beauty of the beach stand in the way of their doing so. In Dublin we are at a somewhat similar stand; and whilst those several communities are thus anxious, and actually labouring and spending to make a present of their abundant supply of liquid manure, there are as many around them willing to pay liberally to get possession of it. There can thus be little doubt that there is a vast amount of capital ready on every hand to be invested in carrying out practically the true idea of bringing the supply and demand which I have just mentioned into profitable contact.

The next want at this juncture is what must be supplied by science—mechanical and chemical. The mechanical means by which our health and wealth can, in this respect, be so materially promoted will, no doubt, claim the attention of the mechanical section of the Association, whilst any contribution towards completing the chemistry of the subject will meet with due consideration from the section which I have the honor of addressing.

Although the great value of the drainings of our cities and farm-yards is allowed by all, those who understand the pre-

sent position of agriculture know that there are some points of considerable practical importance upon which there is a diversity of opinion entertained. In reference to the time and state in which drainings should be applied to the soil there are two opinions and two practices—the great majority being, I am sorry to say, on the wrong side of the question. It is asserted by the greater number of agriculturists that—in the language of the farm—the drainings ought to be allowed to *ripen*, or, in the language of science, to ferment and produce ammonia, before they are administered as food to the plants; the supposition being, that the urea, which constitutes the most valuable portion of the fertilizing constituents of the drainings, must be converted into ammonia before its nitrogen can become available for the purposes of vegetation.

It is a curious and suggestive fact that the Chinese, who are so remarkable for their industry and minute economy, apply their liquid manure immediately, and without allowing time for its fermentation and consequent production of ammonia. They thus, in a great measure, especially for the whole of that period during which the article is in immediate demand to promote the growth of the plants, dispense with tanks for preserving the drainings, and do not incur the loss occasioned by the formation and escape of volatile ammoniacal compounds, which so generally attend the process of what the farmer calls the *ripening* of his liquid manure. It is very probable that these *prima facie* economical considerations were the main reasons for the Chinese adopting this as a practice, and yet certain experiments which I have made satisfy me that they are right in science as well; and I consider it no small matter to have my *earthly* theory supported by such *celestial* practice. That theory is, that nitrogen is as available as food for plants whilst a constituent of urea as it is in its ammoniacal combination; or, in other words, that

urea, without being converted into ammonia, may be taken up into the organism of the plant, and there supply the necessary quantity of nitrogen. The experiments which have led me to this conclusion I shall now proceed to describe.

EXPERIMENTS.

Four earthenware basins, each two feet in depth, and 2½ feet across, were filled with fragments of felspar, of different degrees of fineness; the coarsest fragments being placed lowest. In each of these basins 60 grains of barley were sown on the 5th of May. The basins were then numbered 1, 2, 3, and 4, and in each was placed a portion of an artificial manure, containing the following substances, viz. :—

The double silicate of potash and soda, precipitated carbonate of lime, hydrated sulphate of lime, freshly precipitated phosphate of lime, phosphate of magnesia, and chloride of sodium. The bases and acids of this compound were in such proportion as nearly to correspond with the composition of the ash of the barley plant.

In addition to the above-mentioned substances (which, it will be observed, contained no nitrogen), a solution of urea was applied thrice in each week to basins Nos. 1 and 2, and a solution of sulphate of ammonia to No. 3. No. 4 was intended as a check upon the experiments with the urea, and to it, therefore, no nitrogenous substance was applied. All the basins were covered with glass shades; the air supplied to the interior of each being freed from ammonia by treatment with dilute sulphuric acid.

The urea used in my experiments was prepared by the following process :—

28 parts of dry ferrocyanide of potassium and 14 parts of peroxide of manganese, thoroughly mixed, were heated to dull redness. The resultant mass, after cooling, was treated with

cold water, and the solution thus obtained mixed with 20·5 parts of crystallized sulphate of ammonia; sulphate of potash and cyanate of ammonia were formed, and the latter, on the application of a gentle heat, was converted into urea. I did not separate the sulphate of potash, as its presence did not interfere with the results of the experiments.

The felspar in basins No. 1 and 2 was occasionally washed with distilled water, and the washings tested for ammonia. I did not, however, in any instance, detect the presence of this substance, which proves that the urea was not converted into ammonia.

The barley experimented on was the variety known as *Chevalier* barley. The growing plants were supplied with carbonic acid gas and carbonated distilled water. The plants were thinned at an early stage of their growth, so that there remained but 15 plants to each square foot of surface.

The results of the experiments were as follow:—

No. 1—Period of complete germination—within 5 days.
Period of ripening—within 107 days.
Mean height of plants, including the ears—29 inches.
Average return from the seed—9 stalks.
Average produce in seed—28 grains from each stalk.
Size of grain—14,786 to the pound.
Amount of nitrogen in 100 parts of the dried grain—2,470.

No. 2—Period of perfect germination—within 6 days.
Period of ripening—within 112 days.
Mean height of the plant, including the ears—26 inches.
Average return from the seed—10 stalks.
Average produce in seed—27 grains from each stalk.
Size of grain—14,672 to the pound.
Nitrogen in 100 parts of the dried grain—2,385.

No. 3—Period of complete germination—within 8 days.
Period of ripening—within 105 days.
Mean height of the plants, including the ears—22 inches.
Average return from the seed—12 stalks.
Average produce in seed—25 grains from each stalk.
Size of grain—15,607 to the pound.
Amount of nitrogen in 100 parts of the dried grain—2,388.

No. 4—Perfect germination took place within 8 days, and stalks, on the average, 8 inches in height were produced; but in no instance were seeds developed.

The following conclusions are, I consider, deducible from the results of my experiments:—

1—That the perfect development of barley can take place, under certain conditions, in soil and air, free of ammonia and its compounds.

2—That urea, in solution, is capable of being taken, unchanged, into the organisms of plants.

3—That urea need not be converted into ammonia before its nitrogen becomes available to promote the process of vegetation.

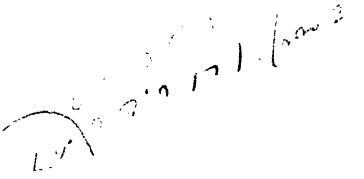
4—That the fertilizing effects of urea are not inferior to those of ammoniacal salts.

5—That there exists no necessity for allowing drainings or other fertilising substances containing urea to ferment; but that, on the contrary, greater benefits must be derived from their application in a fresh or unfermented state.

NOTE.

On Urea as a direct Source of Nitrogen to Vegetation.—We have much pleasure in inserting the following [foregoing] experiments performed by Dr. Cameron, and detailed by him in an essay read before the British Association. The experiments are valuable to the farmer, as showing that the urine of animals may be applied in its fresh state with advantage to the land, thus doing away with the necessity of making expensive tanks for keeping the urine till it has undergone fermentation. Tanks have hitherto been held indispensable when the urine of the animals on the farm has been applied in a liquid state; but these experiments have proved that it may be put at once upon the land, which will receive the benefit of the nitrogen contained in it, before that nitrogen has been converted into ammonia or one of its salts—a change which chemists generally thought it was necessary for it to undergo, before it could be of any use to vegetation.—*Journal of Agriculture.* Edinburgh. October, 1857.

THE END.



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